Dr. Paul E. Sample
Technical Coordinator
Technical Advisory Office

308 Walden Road
Wilmington, Delaware 19803
Phone: 302-656-3212
E-Mail: sample@bellatlantic.net

STATE OF DELAWARE
DIVISION OF RESEARCH
LEGISLATIVE COUNCIL

MUNICIPAL SOLID WASTE PROCESSES
ASSESSMENT OF ALTERNATIVE TECHNOLOGIES

November 20, 2005

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Produced by the Technical Advisory Office
of the
State of Delaware
Legislative Council, Division of Research
in cooperation with
Delaware Environmental Alliance
for Senior Involvement

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Executive Summary

Introduction

In letters from Senator Charles Copeland and Representative Robert Valihura dated June 24, 2005 and August 30, 2005 respectively the Technical Advisory Office utilizing the technical resources of the Delaware Environmental Alliance for Senior Involvement (Del-EASI) has been requested to provide a report on the state of the art for municipal solid waste (MSW) management and disposal.

This report documents the present understanding of technical processes in use or being considered for municipal solid waste disposal and provides an assessment of the merits for each.

The Executive Summary was written by Dr. Paul Sample, Technical Coordinator in the Technical Advisory Office of the Legislative Council, Division of Research. It summarizes the findings and recommendations of Dr. Sample along with a team of technical volunteers from (Del-EASI): Wally Kremer, Chair., Andrew Foldi PhD, Robert Gross, Mary Jane Hofmann MS, Harry Monck MS, Alfred Ostrand, Edith Swoboda.

Assessment of Technical Processes

A. Thermal Processes with Oxygen

Waste to Energy

Pro

- Reduces waste to landfill 90%
- No Waste shipped out of state.
- Eliminates odor and greenhouse gases
- Cleaner work environment
- Uses latent thermal energy
    - to destroy toxic & odor causing chemicals
    - to generate steam, — that in turn
- Can be used
    - to heat — and/or
    - to generate electricity.

Con

- Increases truck traffic as would a landfill.
- Requires extra equipment
    - for sorting recyclables and large items
    - for reducing large items to operable size
    - for eliminating dust, odors and harmful emissions from the stacks.
- Greater initial investment than acquiring new landfill site & site preparation.
- Operating costs higher than maintaining a landfill.
- Negative public perception of "trash burning", "incineration"
- Restrictive legislation.

Tires to Steam - Energy recovery is the single largest use for scrap tires as "*tire derived fuel*". However, since tires do not appear in significant quantities in MSW this technology does not affect the landfill operations and will be addressed in a separate report.

B. Thermal Depolymerization without Oxygen

Changing World Technology (CWT) - This technology is still in development with limited commercial operation. Current operating conditions restrict feed stock variance and require production runs of two hundred tons per day to be economical.

C. Mechanical and Biological Systems

Bouldin Corporation "WastAway" Technology

Pro
- 95% recycle possible
- No waste sorting by householder- uses existing trash pick up
- Low capital investment - [$4million for two-line system that processes 40,000 tons/yr.]
- Low starting investment for smaller jurisdiction.
- Cost equal to or less than tipping fee
- Commercial process demonstrated
- Product marketable for nursery potting and as soil amendment

Con
- Need market development for products
- Testing Delaware municipal solid waste needed to verify product quality
- Product acceptance in Delaware unknown
- Prefer separated yard waste.

Composting

Pro
- Produces humus for a ready market
- Reduces methane emissions
- Can be low capital investment and low operating cost.

Con
- Quality control of large scale operation may be difficult.
- Requires 25 to 150 acres for a 100,000 TPY operation.
- Potential odor problems when out of control
- Inventory and logistics problem to maintain optimum 30/1 C/N ratio.

D. Plasma and other New Technologies

Plasma Gasification or Pyrolysis - Plasma gasification or pyrolysis is experimental technology in field of waste management. However, a technical assessment is given.

Pro
- The higher arc temperature provides destruction of organic compounds, avoiding environmental issues

Con
- Commercial adaption and acceptance not established
- High energy input required; positive energy balance does not look favorable..
- High capital investment [est. $100-300 million dollars for a 1000-1500 ton/day unit]
- High risk in experimental technology

E. Miscellaneous

Landfill Enhancement Methods

Pro - Conventional Landfilling
- Least expensive
- Widely accepted and understood
- Flexible with difficult types of waste

Con
- Waste density lower than other techniques

Pro - Shredfilling
- 32% higher compaction than conventional landfilling
- Binds better reducing wind blowing and rodent/bird attacks.
- Reduction in cover required resulting in less landfill space.
- Heavy equipment passage easier.

Con
- Not all wastes can be shred.
- Added processing step adds capital and maintenance costs
- Reduced daily covering needs further research.
- Equipment downtime for maintenance is greater

Pro - Balefills
- Greater compaction of waste.
- Bird activity at tipping face lower.
- Less odors
- Soil daily cover reduced ~ 50%[A spray-on mixture can be used(Pozzy Shells).]
- Little or no blown litter.
- Reduction in differential settlement.
- Lower operating cost
- "Neater" public perception

Con
- Added processing step adds capital and maintenance costs
- High downtime for maintenance and repair.
- Not all waste can be baled.
- Requires leachate monitoring
- Limited flexibility in waste quantities and types.

Resource Reduction/ Recycling - Not recycling means lost resources and energy and more pollution. Recycling saves landfill space and reduces pollution. Waste is recycleable.

Conclusions

A review of the attached report and references cited leads to the following generalities:

- A single processing scheme is currently not suited for handling MSW efficiently cost considered..
- The most promising scheme appears to be a combination of the "*WastAway" technology*, and a commercial *Composting* process that will accommodate all yard waste as a separate waste stream.
- *Thermal depolymerization* (CWT technology) and *plasma gasification* schemes need to be developed further for commercial reality.
- *Waste to energy* is not a timely solution for dealing with residential solid waste because of the capital investment required. Growing regional electrical power demands may change this assessment in the future.

Recommendations

- **Near Term** - The functional and economic merits of a dual system (*WastAway technology* and *Composting*) need to be explored, since this combination provides the least disruption of residential waste disposal habits while producing locally useful products.

- **Longer Range** - A comprehensive cost analysis (capital and operating) along with energy and material balances should be undertaken for "*WastAway*" *Technology*, *Commercial Composting* and *Waste to Energy* to facilitate proposals for waste management change and/or new business development.. [Note: Waste stream composition can be expected to continue to change by region and time. Understanding this change should be a part of any economic study.]

- Emerging technologies including bio-energy processes should be reviewed again at some point in the future.

MUNICIPAL SOLID WASTE PROCESSES - TASK GROUP REPORTS
November 20, 2005

APPENDIX

I. Waste Management Study - Wally Kremer (Folder 1)*

II. Thermal Processes with Oxygen
- Waste to Energy - Andrew Foldi, Robert Gross, Harry Monck (Folder 9)
- Tires to Steam - Harry Monck (Folder 4)

III. Thermal Processes without Oxygen
- "Changing World Technology" - Harry Monck (Folder 5)

IV. Mechanical and Biological Systems
- "WastAway" Technology Evaluation - Wally Kremer (Folder 6)
- Composting - Al Ostrand (Folder 3)

V. Plasma and Other New Technologies
- Plasma Gasification or Pyrolysis - Wally Kremer (Folder 8)

VI. Miscellaneous
- Landfill Enhancement Methods - Mary Jane Hofmann, Edith Swoboda (Folder 7)
- Resource Reduction and Recycling
  - Alternate Thinking on Waste Disposal - Marlene Rayner (Folder 2)

Footnote: * "Folders" identify original documents as received from Del-EASI by author(s) and subject. Continuity of these folders were retained for record purposes in Division of Research.

Appendix I

WASTE MANAGEMENT STUDY

Interim Report

Del-EASI Waste Management Study
Objective
Technology world wide
Technologies studied
Summary Technologies- Details in Individual Reports

Recommendations for Future Studies

Individual Reports on Technology

BY Del-EASI STUDY GROUP

Andrew P. Foldi, Robert Gross, Mary Jane Hofmann,

Wallace L. Kremer- Coordinator, Harry Monck III,

Alfred H. Ostrand Jr., Marlene Rayner, Edith Swoboda

TRANSMITED TO:

Dr. Paul E. Sample
Technical Coordinator
Technical Advisory Office

State of Delaware
Legislative Council
Division of Research

NOVEMBER 2005

Appendix I (cont)

Waste Management Study

prepared by Wally Kremer, Del-EASI

The Delaware Environmental Alliance for Senior Involvement (DelEASI), a technical volunteer organization sponsored by Retired Seniors Volunteer Program (RSVP), is conducting a study of various technologies to manage Municipal Solid Waste (MSW). Senator Charles Copeland and Representative Robert Valihura have requested this study. The report is being submitted through the Technical Advisory Office of the Legislative Council.

Objective
The interim report identifies, describes and provides a survey evaluation of various technologies to manage MSW and comments on possible future studies.

Technology World Wide
In Europe, Japan and the United States, recycling of recoverable materials and composting of yard wastes are practiced widely. In Delaware, our recycle rate is low and yard waste is still sent to the landfill. In the United States, landfills are still a major way of disposing of MSW, since in our large country, inexpensive land area is available and economics are favorable. Pennsylvania accepts some 11,000,000tons and Virginia some 5,000,000 tons annually out of state MSW. Material from some states is sent to both landfills and Waste to Energy (WTE) facilities in other states where there is excess capacity.

In Europe and Japan, after effective recycling and composting programs, much of the remainder of the MSW is processed through Thermal Technology. Some countries, because of the shortage of land, limit the percentage of MSW that can be sent to a landfill. (European landfill directive: must reduce material going to landfills by 95%). WTE systems have not been installed in United States for years, due to emission concerns and major investment. Meanwhile many have been installed in Europe and Japan.

Waste management technology is continually improving, and new concepts are emerging. Increasing trends in energy costs and conservation will accelerate the advancement. One reference indicates recycling of aluminum will save 95% of the energy needed for new manufacture. A ton of recycled aluminum saves 37 barrels of oil. A recycled ton of paper saves 4 barrels of oil, and burning it saves 2.25 barrels of oil.

Technologies Studied
The study investigated the technologies for managing MSW from the total range practiced or emerging. Report includes discussions on Recycling: for example, Blue Mountain Recycling in South Philadelphia where new technology separates single stream feed (all recycle material in one container) into marketable products and has currently 60% excess capacity. Composting, for

example a local company- W.L. Gore has a patented process using "Gore" fabric to enclose material for aerobic composting, and anaerobic digestion in-vessel technology, which produces methane for fuel is covered. WTE processes – total combustion (incineration), pyrolysis (no oxygen), and gasification (limited oxygen) are included. Environmental controls under new EPA guidelines have enhanced WTE environmental performance, reducing dioxins by 95% and mercury by 90%. Plasma Gasification: although plasma is an emerging technology, it has potential with the higher temperature operation to be a leader in environmental performance. The WastAway process which can process MSW, as is, without separation by households to recover metals, produce compost and rigid products like fence posts and benches may find a place in the various solutions. The Changing World Technologies process, which can reduce organic materials to synthetic oil, is practiced only with a single feed at a single plant. A Tires to Steam process is also reviewed. Landfill enhancements are discussed: shredding or baling the material can save space (20-30%) and cover (reference says 50%). New techniques for all aspects of landfill design are now available. A summary of each report follows and then the individual detailed technology reports that cover the history of the technology and the current state of the art. Pros and cons and technical recommendations are included.

Summary of Technologies- Details in Individual Reports

Recycling - The Recycle Public Advisory Council (RPAC) has been active in recycling since the year 2000, so this report covers only that which would be additive to that effort. DelEASI has a member on the council. Blue Mountain Recycling, a company with a plant in south Philadelphia that separates from a single stream recoverable MSW-- cans, paper, corrugated boxes, plastic bottles, and glass into salable products. A new key feature is the first stage called a VEE screen, which permits glass to be in the stream. This unit in the shape of a slotted V has air blowing through it to separate all paper and corrugated material. All the other cans, plastic bottles and glass pass through the bottom opening. They currently have 60% excess capacity. Many systems, both multiple and single stream, are used in the United States and other countries. The EPA can provide information and educational material. RPAC has reports provided by a consultant, DSM Environmental Services, Inc.

Composting - Composting has been part of agriculture for thousands of years. Modern composting of organics in MSW uses biological organisms (nature's workers) under controlled conditions of temperature, moisture and oxygen content to optimize the production of compost ~~under aerobic conditions. Space (25 to 150 acres) is required for a 100,000ton per year facility.~~ Composting has been both a private industry and public operation in the United States. DNREC has a study group now on composting. The W.L. Gore patented systems uses only minimum space of 25 acres for a 100,000 tons per year facility. Some operations are inside buildings to protect and control the operation. A self-contained automatic unit is available for use; a bank of them could be installed. Anaerobic composting, in-vessel systems in buildings, have been used in Europe to produce methane for fuel and power generation. DNREC has a committee currently studying composting, and DelEASI members are part of that effort.

WastAway Technology - The Bouldin Corporation in Warren County, Tennessee, has a novel, innovative, patented process that recycles 95% of residential Municipal Solid Waste. WastAway has installed a second unit in Coffee County, Tennessee, and sold the technology to Alton Steel Inc. in East Saint Louis, Illinois. WastAway's innovative household garbage recycling process has been awarded the prestigious R&D 100 award for 2005 by the R&D magazine. See www.wastaway.com and www.bouldinlawson.com.

The residential MSW is collected, as now, without separation of recycle material. The fully automated, rugged mechanical process involves shredding and grinding and then heating with steam in a Hydolyzer at about 325F by 125-150 psig steam. Magnets and eddy currents separate metals so that they can be recovered for sale. The product is called "fluff" with the appearance of brown paper pulp. The Corps of Engineers tested this, and uses on Army posts. EPA classifies it as a Class III compost, and Auburn University did an evaluation and found it satisfactory for growing plants. Nurseries in the Southeast praise the product. The fluff is also used as feed to produce by extrusion rigid products such as timbers, posts and benches. Investment in two lines to produce 40,000 ton/year is about $4 million and cost is less than tipping fees at landfills. Requires market development, but may fit needs in certain areas and/or for non separated MSW.

Changing World Technologies - CWT has developed a Thermal Depolymerization process. This unique process copies the geothermal process of nature, using water, heat and pressure to reform industrial byproducts into oils, specialty chemicals, gases, carbon and fertilizer. Currently it only operates on one feed at one plant, but CWT indicates they will be able to process other feeds including MSW. DelEASI members witnessed a bench scale test in Philadelphia. One major concern is that the system requires at least two hundred-ton per day runs with a consistent feed stream.

Tires to Steam - Energy recovery is the largest single use for scrap tires. Often used as dedicated or supplemental fuel called Tire Derived Fuel (TDF) for industrial processes or public utilities. About 101 million tires are converted to energy annually in this way. A plant in Martinsville, Virginia, was visited. A report of the visit with pictures is included in the details. The plant produces low-pressure steam and a wet ash composed of $CaSO_4$ and finely divided iron. Some tires in Delaware are already shipped to a TDF facility in Virginia.

Plasma Gasification - An electrical arc in a gas at temperatures above 7000C produces the plasma. It is called artificial lightning and temperatures are higher than the surface of the sun. The gasification process with limited oxygen is used to produce a synthetic gas of hydrogen and carbon monoxide for fuel. Plasma systems have been small capacity for medical, electrical and chemical wastes. In the last 5 years or so larger systems 300 tons/day for MSW are in operation and even larger ones are planned. All companies indicate they meet EU, Japan and EPA regulations and 99.9999% Destruction Removal Efficiency. The total system includes many stages of environmental control equipment and very high temperature decomposes all material to the elemental form. Web site www.recoveredenergy.com has a technical discussion why high temperature of a plasma is critical to destruction of all organic compounds and why they believe plasma and therefore is best route to control. (See details). A plant in Japan that replaced an incinerator reports 100 times better environmental performance. This is an emerging technology with the potential to be a leader in environmental control and should be monitored and evaluated for the state of the art. A major investment – hundreds of millions of dollars – would be needed for the sophisticated technology, which reduces material feed to a few percent of ash, and supplies energy.

Waste to Energy (WTE) - WTE can be practiced by all three modes – pyrolysis (no oxygen), gasification (low oxygen) and combustion (total &excess oxygen). Many reports are available- see detailed section. The United Nations guidelines give a good discussion of different types of apparatus and the report indicates the environmental releases can vary over several orders of magnitude, based on the environmental controls included. A mass burn unit burns all the MSW as received, whereas a Refuse Derived Fuel (RDF) unit feeds preprocessed MSW. The Air Pollution Control Devices (APCDS) are critical to environmental performance and stages of scrubbers, bag filters, activated carbon and other devices are used. Techniques of injecting chemicals are also used in some units to capture pollutants. All operating units in the United States were required to upgrade to the EPA Maximum Available Control Technology (MACT) which the industry indicates has reduced the dioxin discharge by 95% and mercury by 90%, now lower than coal fired plants. Europe has continued to install units, while none have been installed in United States for years. Harrisburg, PA is to startup a new unit in 2006 with similar technology as the Tulsa, OK facility. In the details section, the plants in Baltimore, MD, Onondaga County, NY, Tulsa, OK. and Basel, Switzerland are reviewed. DSWA had a consultant study completed for 12 units in 1999. The report is available and a summary magazine article is located at web site. www.forester.net/mw_0209_trends.html. The WTE route requires large investment hundreds of millions of dollars and the environmental equipment and control technology are critical to performance, but destroys 90% or more of the feed, and supplies energy.

Recommendations for Future Studies

Waste Prevention - On the EPA pyramid of managing MSW Source Reduction is the top end of the material management hierarchy, because it is waste prevention. Reuse is the second item. During the past 35 years, the amount of waste each person creates has almost doubled from 2.7 to 4.4 pounds per day. Waste prevention is the best way to stop this trend. Governments such as Palo Alto, California, are pursuing zero waste. Zero waste seeks to eliminate waste wherever possible by encouraging a systems approach that avoids the creation of waste in the first place.

Source reduction and reuse practices abound and technology is usually not a concern. One example of source reduction is to sell powders in large bulk units or as slurries in railcars, trucks to save paper bags, pallets and wrapping. Reuse of pallets and corrugated boxes is another. Giving clothes to help victims or to charity is another. A detailed search and then publicity of known procedures may be a start. Some communities have a place where you can bring things such as used furniture and goods and leave them for others to pick up and use.

Management of MSW Technical Studies

Our technical study focused on where technology enters the picture to manage MSW. This interim study was limited by time. One focus needs to be new and emerging technology. This study did review several of these, however an even broader search and review would be of benefit. The biochemical approaches including fermentation, acid hydrolysis, anaerobic digestion are now being developed and commercialized and need further study. Changing World Technologies and WastAway need to be followed and more data obtained and possibly specific tests performed.

Recycle Public Advisory Council (RPAC) has investigated recycling The DNREC web site under recycling has all the RPAC information. Different systems are practiced for both multiple and single stream recycling. The consultants evaluated alternate systems and recommended single stream. Technology for the single stream system has been enhanced so that paper, corrugated boxes, plastic bottles, cans and even glass can be separated and marketed. Such a facility can be toured in South Philadelphia. Recycle technology just needs monitoring to keep up with new developments.

A group sponsored by DNREC is studying composting of yard wastes. DelEASI members are part of this study and will monitor and contribute to its efforts. Many approaches are practiced and therefore defining the best technology in the various approaches must be completed.

Europe has been installing new Waste to Energy plants, but the United States has not in many years. A new WTE plant will be installed in Harrisburg, Pennsylvania, in 2006. A consultant who issued a report to DSWA in 1999 studied the WTE technology at 12 locations: 1 in Europe and 11 in the United States. Our study reviewed locations in both parts of the world. Future studies would need to be broadened and be of more depth to ascertain the best process and performance. The Plasma route is emerging and its advance should be monitored.

Landfill technology is changing and concepts that enhance the operation have been commercialized. Shredding and baling the material saves space and cover material. Additional information on performance of equipment should be obtained. As with much of the changing technology, visits to facilities may be beneficial for understanding.

An integrated solid waste disposal system, using several technologies, may well give the best result. As recycling and composting are implemented, those technologies will divert significant tonnage of material from the landfills. Understanding the composition of the remaining material will be an aide in choosing how to deal with the remainder. The options to different integrated systems must be outlined and an in-depth analysis performed.

Appendix II

THERMAL PROCESSING WITH OXYGEN

WASTE TO ENERGY - A Study of Partial Incineration of Waste

Prepared by: Andrew Foldi, Robert Gross, Harry Monck III of Del-EASI

Summary

Burning of solids wastes to produce energy while greatly reducing the amount of waste that has to be landfilled is a viable, environmentally safe and economically viable means of dealing with the increasing amounts of trash that has to be disposed of. There are more than 100 waste-to-energy (WTE) facilities in the U.S. providing communities with clean, reliable energy with less environmental impact than almost any other fuel-based source. Nationwide, WTE plants generate nearly 2500 megawatts of electricity with an estimated saving of 1.3 billion gallons of fuel oil. These plants have been equipped to use EPA's Maximum Available Control Technology to reduce the emission of mercury and other volatile metals as well as harmful/toxic organic pollutants to a very small fraction of those emitted by coal fired power plants.

Background

With the increasing amounts of solid municipal waste, it has become necessary to find other methods of disposing the waste short of landfilling it. Among the many practical and potential alternatives is the thermal decomposition of the burnable portion of this waste, as well as the recovery and disposition or the re-use of the non-burnable portion, respectively. This survey describes, in general, the various methods available to achieve these goals.

The Source

There are basically two kinds of solid wastes, identified as municipal and industrial. Municipal waste implies trash generated by households, while the term industrial waste encompasses all kinds of refuse from manufacturing, trade, transportation, health[1] and hospitality industry (hotels, restaurants of any size)[2]. While collecting basic information for the industrial waste "production", the size of the contributor is usually taken into consideration.

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[1] Hospitals, medical facilities, doctors' offices, medical labs, etc.

[2] When collecting data to calculate heat balances, the industrial side of the waste stream is broken down into many more distinct categories.

When referring to municipal waste producers, the producers are usually counted only as "households", regardless of the number of people in the household.

Both kinds of waste contain intrinsic material value and latent heat value, in addition to a relatively small amount of material having neither. The latter still will have to be disposed of in a landfill.

The Value of Source

When the recovery of some of the components of waste is a factor, one must take into consideration the value of these components as well as their relative ratios. Ideally, valuable wastes or by-products should be recovered by the producer, usually at the site of production. Recovery of silver at/from photo-processing labs, or of gold dust at jewelers are well-known examples. Some materials have intrinsic value only if they are separated from the main bulk of the trash. Aluminum cans are a good example[3]. Others may have other intrinsic values but only as far as their latent heat content is concerned. Some materials have both material and latent heat values (e.g., newspaper or plastic bottles). These materials should be either recycled or used as a source of heat energy, depending on the then current market value[4] of either "re-use" option.

If material recovery is not considered, then the most efficient reuse is the conversion of the combined wastes' latent heat content to energy[5].

General Description of a Thermal Conversion Unit

Regardless of the final recovery/disposal goals, all such processing plant operations consist of the following steps:

1. Transfer trash from the collector to the plant[6]
2. Homogenize the collected refuse for even burning
3. Introduce the wastes into a drying zone[7]

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[3] Recycling aluminum saves about 95% of the energy (electricity) if starting from "scratch", i.e., bauxite. A ton of recycled aluminum saves about 37 barrels of oil (type of oil not specified; crude oil is assumed).
[4] Recycling a ton of newspaper saves about 4 barrels of oil but burning it produces only the same amount of BTU as 2.5 barrels of oil.
[5] This is called "mass burning".
[6] Separation of recyclable material may take place at this point if desired.
[7] Collection and condensation of the water vapor may be used to generate "pure" water for step 5.

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4. Heat the mostly dry material in a kiln that produces sufficiently high temperature to decompose and oxidize most organic materials, including odor causing and carcinogenic material[8]
5. Generate steam from pure water in the boiler[9]
6. Operate turbines with the high-pressure steam[10] so obtained and generate electricity
7. Use a portion of this electricity[11] to maintain plant operations and introduce the remainder into the high- tension electric grid through a power sub-station
8. Re-use the spent steam[12]
9. Remove solid particles from the stack emissions[13]
10. Remove gaseous waste materials[14] harmful to the environment and/or to the public[15]
11. Collect and neutralize the liquid results of the purification process before either reuse or discharge
12. Collect the solid residues (mainly fly ash and slag), separate large, recyclable materials from it, and ship the rest to landfill.

While these steps of operation seem to be cumbersome, landfilling itself requires many more steps than just dumping the garbage onto a heap. Also landfilling generates methane gas and obnoxious odors. The former, being one of the more damaging greenhouse gases, has to be piped to, and burned in, a power plant, while the latter is the cause of much of the public's complaint.

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[8] The key variables controlling the combustion process are residence time, combustion temperature, moisture content and size distribution of the waste feed. On initial start-up, the chamber is heated to 750 °F by oil or natural gas. During normal operation, the temperature exceeds 1800 °F and the residence time is over 1-2 hours.

[9] The boiler walls are water-jacketed, and if the grate is not a moving (e.g., reciprocating) type (see Reference 3), then the stationary [illegible] are also water-cooled.

[10] Above 750-800 °F

[11] About 10 to 15%

[12] Either by using it as a low-pressure steam feed or by condensing it in cooling towers(s).

[13] By bag filters, electrostatic filters and/or cyclone separators. The remaining emitted particles are of less than 3 microns in size.

[14] To reduce the formation of nitrogen oxides (NO_x), dry urea is introduced in the combustion chamber. Activated carbon is injected to remove dioxins and furans, as well as mercury. See Reference 3 for the description of an operating plant, and Reference 4 for a summary of best available technologies.

[15] By liquid scrubbers using lime (or similar) suspension to remove acidic wastes; by the use of catalytic converters to reduce/eliminate nitrogen oxides and an array of dioxin and furan compounds.

Discussion

We have investigated several already operating systems through Internet searches. The focus of our study was to alleviate the fear by the public (justified by earlier, crude attempts at burning trash) of unsightly, odor-causing, unhealthy, smoke-belching facilities — not to provide a blueprint for the most efficient incineration methods. Current climate (through various legal caveats) prohibits the operation of any incinerator within the State of Delaware. Therefore, any technically detailed study and planning should be undertaken only after these legal barriers have been removed. Nevertheless, we are including four examples to show what benefits could be derived from the waste-to-energy methods.

1) The ***Refuse Energy Systems Company*** has a plant near Baltimore, MD that has been in operation since 1984. It has the capacity to dispose of 2,250 tons of municipal solid waste (MSW) per day, while generating 60 megawatts of electrical energy. This operation is classified as "mass burn" because no recycling is involved: all garbage as collected is fed into the boilers. The collection pits being under negative pressure (the air is sucked into the combustion chambers), odors and dust are prevented from escaping into the outside environment. The residence time in the furnace for any garbage particle is about 1 hour.

The plant operates 3 lines (each capable of 750 tons/day) on a 24/7 basis, shut down only for maintenance. Natural gas is used as the auxiliary fuel source, especially at start-up. The combustion temperature is over 2500 °F.

The plant produces high-pressure steam (850 psig at 825°F) that is converted to electricity, high-grade steel and non-ferrous metals that are sold to the scrap market, and ash that — after treatment — is sold as daily cover or separating layer for landfills. The volume of the garbage is reduced by 90% in this process, while generating steam for heat[16], or electricity[17], or a combination of both. BRESCO (as this plant is known) can provide up to 300,000 lbs/hour direct steam to supply heat or cooling[18] to downtown Baltimore.

For further details, see References (1) and (2).
N.B. There are 16 plants like this in operation in the US.

2) In New York State, the WTE facility of the ***Onondaga County Resource Recovery Agency*** has, since 1994, processed over a million tons of garbage and serves electricity to about 20,000 homes while operating consistently well within the environmental requirements established by the New York State Department of Environmental Conservation.

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[16] Capacity: 500,000 lbs of steam per day
[17] Capacity: 60,000 kW electricity
[18] In the same manner as natural gas heating is used to cool refigerators via a compression/expansion/cooling principle.

An interesting aspect of their operation is that each in-bound truck is checked on the scale with a radiation detection device capable of detecting an object as small as a Q-tip containing low-level radioactive waste. Such a truck is diverted to another location where its contents are unloaded, the radioactive material(s) separated and safely stored until they have either decayed or are transported to an out-of-state disposal facility.

Income from this WTE facility (including tipping fee) is used to support the expenses of the plant and underwrite recycling, household hazardous waste collections, the operation of two compost sites, development of a county landfill, a pair of waste drop-off sites, and extensive public education. See Reference 5 for details.

3) In Oklahoma, ***W.B. Hall Resource Recovery Facility*** (a.k.a. Tulsa Resource Recovery Facility), retrofitted in 2004 with Barlow's Aireal™ Combustion System, has been serving the Greater Tulsa area since 1986. It has two mass burners and one new combustion system, both with water-wall boilers. Each line can process 375 tons of trash per day, with a combustion capacity of 1,125 tons/day. The plant's storage pit capacity is 3 days. It can generate up to 240,000 lbs/hour of high-pressure (630 psig/700°F) steam — that is supplied to the nearby Sun Refinery — or, when not exporting steam, 16.5 MW (16,500 kW) of electricity — to AEP Public Service Company of Oklahoma. Air quality control includes carbon injection, a semi-dry scrubbing system, fabric-filters in baghouses and continuous emission monitoring.
N.B. A similar WTE facility will go on stream in Harrisburg, PA in January 2006, with a combustion capacity of 800 tons/day and an output of 23 MW (23,000 kW) of electricity and 50,000 lbs/hour of steam. (See details for both plants in Reference 8).

4) ***Trash re-utilizing facility (KVA)***[19] at Basel, Switzerland (Reference 9). The current, modernized KVA Basel facility began operation at the beginning of 1999, and has been serving the City of Basel, the Canton of Basel-Landschaft, and the neighboring Duchy of Liechtenstein since. It's trash burning capacity is 190,000 [metric] tons and accepts municipal garbage from 700,000 residences and industrial waste from 300,000 work places.

Non-burnable, partially-burnable or obstructing wastes hinder the oven supplying devices, do not burn completely and put unnecessary burden on the infrastructure of the facility. Therefore, these must be either removed or reduced in size before the incineration[20]. Special emphasis is placed on not mixing electrical/electronic devices with municipal garbage. In Europe, these devices are taken back by the retail

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[19] partner of SwissPowere; KVA is the German acronym for "Trash Burning Plant"
[20] A *very* detailed description is provided for the public and the plant operators, listing all the kinds and sizes of objects that should not be mixed in the municipal garbage that is fed into the burn chamber.
See Reference 9 and Appendix where translations of the German texts are collected.

stores where they were sold. Also, KVA Basel maintains an electronic collection site where individual households and small businesses can take their respective wastes.

Instead of repeating the process, a colored cross-section diagram — showing both the complexity and the compactness of the plant — is shown in the Appendix.

The following types of wastes are not allowed to be deposited in the waste stream:

"Value materials" (paper, corrugated, glass, scrap iron, etc.)
Electric and electronic wastes (including batteries and fluorescent tubes)
Wet wastes (sludges, wet leaves, street sweepings, and liquids)
Untreated dust
Sulfur-containing material, rubber articles, asphalt, etc.
Green wastes [grass] and other compostable wastes
Microbiological wastes
Flammable or explosive materials
Obstructive goods over 6-1/2 ft. long and 3-1/4 ft. wide
Wooden beams and plastic parts/tubes over 3-1/4 ft. long or if more than 5-1/2 in. dia.
Plastic barrels if larger than 13-gallon capacity.

When trash is incinerated, remnants (ash) are generated; the volume of the trash is reduced to 10% through incineration. This remaining material is disposed of — according to its environmental harmfulness — in different landfills. In the Canton Basel-Landschaft, about 35,000 tons of cinders (ashes) are transported by train to the municipal landfill. 5,500 tons of dust from the electrostatic filters and 250 tons of sludge from the water-spray scrubbers are shipped to an abandoned salt mine near Heilbronn (Germany).

The City of Basel provides the largest distance-heating network in Switzerland with 45,000 households, 250 industrial and trade sites, 200 public buildings and 13 hospitals served by it. Nearly one half of this heat comes from KVA Basel through the thermal re-utilization of wastes. In addition, various large factories in the neighborhood are also provided with steam for their production cycles.

The overall efficiency level comes close to 80%, a top value across Europe. KVA Basel was built specifically for the burning of municipal waste; this has the same burn characteristics as brown [soft] coal; once ignited, the waste burns by itself. They claim, there is no need for additional fuel for the burning process, such as oil, corrugated board or paper. Their energy balance in 2004 was as follows:

Waste Input	14.77 GWh Electric[21] Current Output	2.6 %
567.87 GWh	356.84 GWh Distant Heat Output	62.8 %
	80.35 GWh Steam Output	14.1 %
	3.88 GWH lost	0.7 %

[21] 1 Gwh = 1000 Mwh = 1,000,000 kwh

The plant operation complies with the following international industrial norms:

ISO 14001 — encompasses environmental compliance

ISO 9001 — deals with manufacturing and organizational aspects.

A special study was undertaken (Reference 10) to study the efficiency of the KVA Basel operation. While the economic calculations are interesting, the collected material balances (with detailed stream compositions) are most revealing, and are reproduced below. The samples were collected daily over a period of 15 days: "Emission" at exit from the chimney; "Ash" at the exit of the ash silo; "Sludge" at the emptying of the filter press; "Slag/cinders" at the top of the slag heap.

INPUT

Garbage	1 ton
Air	5600 m^3
Drinking water	0.2 m^3
Groundwater	1.4 m^3
Chemicals	
25% NH_4Cl	4.1 kg
CaO	3.1 kg
Polyelectrolyte	4 mg
Sulfide (TMT 15)	40 g

OUTPUT

Emission	5992 m^3
HCl	1.2 g
SO_2	57g
NO_x	254 g
CO	18 g
Organics	2.6 g
Dust	1.7 g
Ammonia	3.1 g
Ash	30 kg
Chlorides	1890 g
Sulfates	1280 g
Cd (cadmium)	3.74 g
Cu (copper)	68.1 g
Pb (lead)	95.0 g
Zn (zinc)	241 g
Hg (mercury)	< 0.001 g

Sludge	1.3 kg (TS [total solids?] 29%)	
	Chlorides	1540 g
	Sulfates.	24.1 g
	Cd	0.003 g
	Cu	0.014 g
	Pb	0.035 g
	Zn	0.135 g
	Hg	0.181 g
Slag/cinders	180 kg (TS [total solids?] 86%)	
	Scrap iron	32 kg
	Chlorides	273 g
	Sulfates	658 g
	Cd	< 0.02 g
	Cu	270 g
	Pb	52.0 g
	Zn	101 g
	Hg	0.001 g
Waste water		0.8 m^3
	Chlorides	4390 g
	Sulfates	690 g
	Cd	< 0.01 g
	Cu	0.03 g
	Pb	< 0.1 g
	Zn	0.012 g
	Hg	< 0.00 g

Now we are ready to objectively discuss the advantages and drawbacks of thermal waste decomposition:

PROS

1) Greatly, up to 90%, reduces the amount of waste that has to be landfilled (which was the primary goal of this study).
2) Eliminates the need to ship waste out of state.
3) Eliminates the odors emanating from landfills as well as harmful greenhouse gases (if those are not reclaimed).
4) Creates a cleaner environment for the employees of the enterprise.
5) Uses the latent thermal energy of burnable matter to generate heat
    - o to destroy toxic chemicals
    - o to destroy odor causing chemicals
    - o to generate steam, — that in turn
6) Can be used
    - o to heat — and/or
    - o to generate electricity.

CONS

1) Increases truck traffic at location (but not more than if wastes were landfilled).
2) Requires extra equipment
    - o for sorting and removing items that are
        - oo recyclable
        - oo too large to feed into the burn chamber
    - o for reducing large items to operable size
    - o for eliminating dust, odors and harmful emissions from the stacks.
3) Requires much greater initial investment
    - o than acquiring a new landfill site
    - o for site preparation.
4) Operating costs are higher than maintaining a landfill.
5) Public currently has a negative perception of "trash burning" or "incineration" (will need extensive public education and PR).
6) ~~Restrictive legislation.~~

GENERAL COMMENTS

Regardless what method or process is chosen, the following criteria have to be evaluated in detail:

Technical Aspects involve the flexibility of the system; the minimum economically viable size and the potential for scale up in the future; the risks of malfunction; the need of process water; the efficiency of conversion.

Siting and Regulations involve the proximity of the municipal solid waste source and the disposal distance of the residue; the necessary footprint; the minimum stack height; infrastructure requirements and availability; regulatory restrictions and permitting; public acceptability.

Cost Considerations imply not only the net costs (capital plus operating costs less revenues), but also the ability to market the products (recyclables, electricity, steam), as well as the financial risks, performance guarantees, and insurance. It is estimated (Reference 1) that the capital costs for a WTE plant could range for $ 110,000 to $140,000 for each ton of daily capacity. The land acquisition costs will depend on the actual siting of the plant. The estimated revenues from the electricity sold are between $20 and $30 per ton of municipal waste, the variability stemming from the pretreatment options of the raw waste and the efficiency of the equipment. Four cents per kWh were used for these calculations.

Environmental Effects entail both regulated and potential toxic emissions; residual wastes; visual impacts; nuisance factors (odor and noise); and worker safety and health issues.

Suggested Elements for a Successful Waste-to-Energy Operation

1. Site the plan away from inhabited area, preferable close to a power station and/or an existing landfill and/or near a commercial facility that could utilize steam, either as it is supplied by the WTE plant or as a feedstock for high-pressure steam[22].
2. Reduce the visual impact. A waste incinerator is a prominent feature in any landscape. However, there have been many designs that result in visually unobtrusive, yet impressive landmarks. Also install soundproofing into the walls, thereby creating an operating facility that is neater looking, less smelly and less noisy than a landfill operation.
3. Enclose all operating areas, especially the waste collection facility, to prevent noxious odors from escaping into the environment. Negative pressure in the truck unloading area is necessary to achieve this.
4. Provide easy access for trucks delivering waste.
5. If possible, collect industrial waste with high caloric[23] value (especially organic wastes from hospitality establishments: restaurants, fast-food, hotels, school and hospital cafeterias) and combine with "normal" municipal wastes. This is especially beneficial if one separates and removes recyclable "thermal value" materials, such as paper. [EPA estimated (Reference 6) that in 2003 *municipal* solid waste contained 83% burnable waste, most of it (42%) paper

[22] An ideal location could be next to the current landfill in New Castle County because of the proximity of a coal fired power station that could utilize the steam.

[23] Also called "calorific" as in a study (Municipal Solid Waste Incineration) prepared for The World Bank in 2000.

products. Removal of plastics (14%) further reduces the caloric value of the waste. And if yards trimming are diverted to composting, another 14% are "lost" for combustion.]

6. Provide for large enough waste collection bins at the plant to provide for greater homogenization of feedstock. Many current plants have a holding bin with a 3-day to one-week capacity.
7. Eliminate large, non-burnable objects by
   a. removing metallic objects
   b. reducing (hammer-milling) to small enough size.
8. Use high enough temperature (degree to depend on the eventual design) in the burning to get rid of odor and harmful by-products of incineration, especially the array of toxic dioxins.
9. Consider using water-cooled grates in the burner to allow higher burn-chamber temperatures in the kiln.
10. Reduce the need for "virgin" water for the operation by reclaiming used water from the cooling towers and scrubbers (with sufficient purification that may be necessary anyhow for the legal release of wastewater into the environment.
11. Install catalytic beds to destroy traces of dioxins, furans and NO_x.
12. Remove (if step 7.a was not involved) metallic residue from the ashes. Zinc has been successfully and economically recovered from ashes where the wastes contained unusually large amounts of batteries.
13. Remove (leach out) heavy metals from the ashes, to be able to deposit the "clean" ashes in a regular landfill
14. Provide for a separate "toxic" landfill for all residues that cannot be shipped to a regular landfill
15. Partially dry any sludge-type residues intended for a landfill, to reduce the volume and weight of the material to be transported.

To improve the overall economical impact of waste handling, the following steps should be considered:

(1) Segregate recyclables from the collected waste stream before it reaches the WTE plant
(2) Sort the recyclables at a separate location and re-introduce their intrinsic material (not calorific) worth into the manufacturing cycle. The most obvious examples are metal cans, glass, newspaper, cardboard, corrugated board, all types of plastic bottles/cans
(3) One has to calculate whether any of the burnable items under (2) has more economical value if it is recycled or if it is left in the incinerator waste to reduce the need for addition fuel to achieve the high enough temperatures, mentioned in 8. above [N.B. Some literature source [Reference 9] claims that "for the burning process there is no need for additional material, such as oil, corrugated or paper"].

Conclusion

Waste-to-Energy facilities can provide an environmentally friendly, cost-effective, efficient way of extending the life of a landfill, reducing greenhouse gases and producing steam/electricity for homes, schools, hospitals or local industry. Municipal solid waste is a renewable, sustainable, abundant source of energy. By integrating curbside recycling and a recovery facility at the WTE plant, the quality of the "fuel" for the WTE plant can be improved and the ash residue reduced.

An integrated solid waste disposal system, including recycling, WTE and landfilling will give the best results.

It is interesting to note — as an afterthought — that a current (November 7-8, 2005) World Conference [24] in Beijing on Renewable Energy has been called to discuss in detail other sources of renewable energy, creating the impression that WTE is somewhat of an accepted, established, "old hat" technology. In solar energy Germany and China are the leads, in wind energy Spain is the frontrunner, and in biofuel production Brazil excels[25]. See Reference 12 for more detail.

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[24] with 100 countries attending

[25] yearly producing enough biofuel to replace 33 million liters (8.7 million gallons) of gasoline. The methanol produced in the process is enough to replace 1.2 million liters (300,000 gallons) of gasoline.

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(2) www.ocrra.org/WTE.html
(3) WTERT, www.columbia.edu/earth/wtert/html
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RAMBOLL Waste to Energy brochure
www.ramboll.dk/docs/dan/Pressecenter/Publikationer/Faglige/Affald/Waste-t-Energy/pdf.
Has great pictures of 7 WTE plants; how neat a WTE plant could/should look (3 pages copied in the Appendix)

Appendix

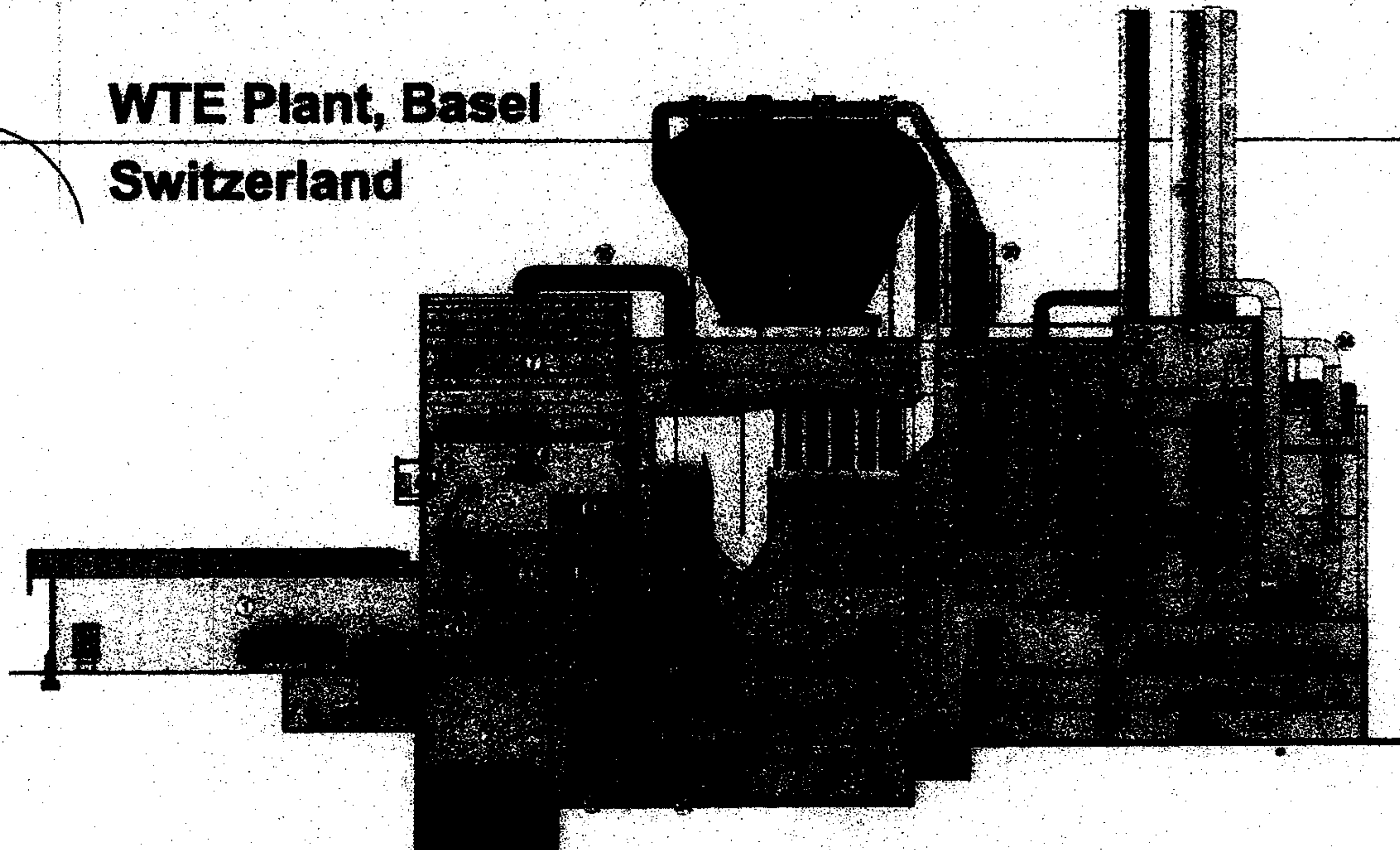
Potential Methods to Segregate Recyclables from the Waste Stream

Blue Mountain Recycling — with facilities in Philadelphia and Montgomeryville, PA — separates and recycles materials from municipal wastes into salable products. The Philadelphia facility is presently operated at 60% of capacity with 1.5 shifts and 5 days per week with 65 employees including maintenance which is done in-house on off-hours. They have a second facility in Montgomeryville, PA that has been recently started up and is operating at about 20% of capacity. The Philadelphia plant is presently processing 10,000 tons/month, at Montgomeryville 5,000 tons/month of trash. Transfer stations have been established in other communities in PA and NJ.

They can process either pre-separated materials or a single stream. The single stream can contain all forms of paper and cardboard, aluminum and steel cans, narrow neck plastic containers and glass. At the start of the process, paper and corrugated material first are blown away from the other material at the innovative VEE separator. The paper goes higher since it is lighter than the corrugated material: so they are also separated. Cans, glass and plastic exits at the bottom and then are separated by gravity, eddy currents and magnets. Glass is eventually ground up into small pieces with no sharp edges, so broken glass in the initial feed is not a problem. Products are sold allover the United States and to Mexico and Canada. Waste material brought in by truck and the recycled products leave by truck or rail. A rail loading facility is in the plant. Their recycling partner/customers include Budweiser for aluminum cans, U.S. Steel for the steel cans, Kimberly Clark and other paper companies for the paper.

To encourage recycling, Blue Mountain Recycling is working with RecycleBank — an innovative approach by two Philadelphia natives with excellent backgrounds in economics. RecycleBank (partly owned by Columbia University) has pioneered a concept of paying for recycled materials with coupons that can be redeemed at participating merchants. This has proven highly effective in sections of Philadelphia. Based on weight recycled material, the resident receives coupons with value up to $300 per year.
For more information see www.bluemountainrecycling.com and www.RecycleBank.com

WTE Plant, Basel
Switzerland



Technical data	
Annual capacity:	240,000 t/[illegible]
Number of lines:	2 ([illegible])
Waste capacity per line:	15 t/h
Steam output per line:	55 t/h
Thermal output:	47 MW
Steam pressure:	40 bar
Steam temperature:	400°C

1 Tipping belt (train / truck)
2 Waste bunker
3 Bulky waste cutter
4 Metal separation
5 Crane operator cabine
6 Waste crane
7 Crane maintenance
8 Charging hopper
9 Secondary air system
10 Waste feeder
11 Grate
12 Combustion chamber
13 Grate siftings conveyor
14 Slag discharger
15 Primary air system with air preheater
16 Steam boiler
17 Fly ash transport (boiler)
18 Electrostatic precipitator
19 Fly ash transport (electr. Prec.)
20 DeNOx-plant
21 Economizer
22 Quench / acidic scrubber
23 Basic scrubber
24 Aerosol separator
25 Induced draught fan
26 Stack / emergency stack
27 Emergency fan
28 Slag conveyor belt
29 Slag bunker
30 Slag crane
31 Turbine / Generator
32 L / M - Voltage switch gear
33 Hot water exchanger
34 Heating condenser
35 Hot water accumulator
36 Hot water pumps
37 Compressor room
38 Emergency generator
39 Sewage water treatment
40 Control room
41 Fly ash silo

ABB Enertech Ltd
Brunngasse 4, P.O.Box
CH-8401 Winterthur, Switzerland
Phone +41 (0)52 266 91 11
Fax +41 (0)52 266 91 12

ABB Enertech Ltd
Römerstrasse 36, P.O.Box
CH-5401 Baden, Switzerland
Phone +41 (0)56 205 58 58
Fax +41 (0)56 205 36 20

Service
Hot-line +41 (0)56 205 31 31

Internet
http://www.abbenertech.ch

ABB

ABBEN / 013e / 0[illegible] Interact & Design, Gebenstorf

Appendix II (cont.)

THERMAL PROCESSING WITH OXYGEN

Tires to Steam - Tire Energy Corporation

Prepared by Harry N. Monck Del-EASI

Introduction

Energy recovery is the single largest use for scrap tires. Often referred to as Tire Derived Fuel (TDF),is being used as a dedicated or supplemental fuel for cement kilns, paper mills electric utilities and dedicated tire to energy facilities. Presently about 10 1 million tires are used annually in this way. Most of the tires must be altered to be used as TDF. Some have the bead (metal rim) removed. Some must be shredded or chopped. This operation does not accept dirty tires. Dirt is seen by the knives as grit. This dulls the knives and stops production until they can be sharpen. Only in Cement kiln where whole tires are used can they accept dirty tires. They do not use tires filled with mud or water for obvious reasons . Having tires enter a kiln adulterate with these materials is inviting a steam blast. Metal from the bead is recovered from some utility burning systems. However the Tires to Steam system can use wet tires and dirty tires.

Summary and Conclusions

This technology has been being worked on for many years. TEC has finally solved most of their problems and moved from prototype to a full size working plant. The plant is located in Martinsville VA.

Since tires do not appear very often in MSW this technology would not affect the landfill operations. Tires that are accepted are chopped and delivered to the land fill from salvage yards , tire sales, and an occasional service station. Whole tire are recovered by DSWA and transported to Loreton VA to be used as TDF. DSW does not want tires and charges a high tipping fee.

Process: I have reproduced some information from TEC together with photos of the plant. I have also included a Memorandum from Bill Harris of DNREC air management section written after he visited the plant in July at the request of Harry Monck and Paul Sample. His memo fully describes the process and gives some insight into the some of the limitations he perceives about TEC and what they need to do before they could apply in DE.

Products: They produce low pressure steam and a wet ash composed of Ca S04 and finely divided iron. Dust from the bag filters is also recovered.

References: These are attached and should be read to obtain a complete picture of this technology.

Appendix III

THERMAL DEPOLYMERIZATION WITHOUT OXYGEN

Changing World Technology (CWT)

Prepared by Harry N. Monck, Del-EASI

Introduction

"Changing World Technology (CWT) is devoted to finding solutions for two critical global problems-our ever increasing demand for energy, and our need to create and maintain a safer and healthier, cleaner environment. CWT's most successes full process to date is the development of the *thermal depolymerization process*. This unique process copies the geothermal processes of nature using water, heat and pressure. to re-form industrial byproducts into oils, specialty chemicals, gases, carbon and fertilizer. It is this unique process that simultaneously reduces dependence on imported oils and other resources as well as our need to dispose of waste... . "

This technology has been around for many years. It is a thermal depolymerization, hydrolysis system. The claims are that this technology can make "oil" out of anything organic. They have set up a pilot plant ant the Philadelphia Naval Business Park. Many from Del-EASI attended a demonstration of the technology on a bench scale set up. As advertised an oily substance was formed also methane gas and pure water. In the reactor containing "ground tires" a residue of carbon black and fine metal particles were recovered in addition to the materials mentioned above. They, at that time had a major customer who was building a plant. Con Agra was going to use this technology to dispose of their Turkey processing plants (Butterball) waste stream. They hoped to produce oil that would be used to supply energy to run the plant and a bone meal substance to be used in Con Agra fertilizer and feed operation.

Summary and Conclusions:

To the scientist this is really neat stuff. In reality it has many draw backs. The process conditions must be adjusted to the materials being processed. Even conducting a lab prep does not give sufficient information to adjust the main unit. Therefore must time and effort is spent "tweaking" the system. If a large amount of one product is being run the system can be set and continuous runs are possible. The other major concern is that this system requires at least a two hundred ton per day runs to make it financially viable.

As mentioned in the introduction Con Agra has built a plant and has been running it after extensive design changes. A recent Wall Street Journal article indicated Con Agra maybe having second thoughts about this technology.

I would not recommend this approach for MSW.

Process: The material is slurried with water and then processed through a Toronado mixer(Digester) which can easily handle most waste-water as the diluent lubricant make size reduction easy and low maintenance. The resultant slurry containing particle 1/2inch or below is fed through progressive cavity pumps to the reactor. The pimps are capable of generating high pressure as needed (about 600psi) and the slurry is heated by waste heat recovery exchangers to about 3 5 0 degrees F followed by trim fuel gas heaters (using fuel produced by the process) to about 500 degrees F . When the reaction is complete the pressure is released in three steps . The first produces 100 psi steam the second produces 50 psi steam the last produces utility quality steam. Minerals are separated out at this point and the liquid proceeds to the reformers. This process used in petroleum refineries , "re-forms" the higher molecular hydrocarbons , breaking down the long chains at about 850 degrees F , also generating coke or carbon black. The solids and liquids are separated in a continuous centrifuges and then heated and distilled. To remove the light gases and remaining water. The resulting oil is of high quality surpassing API 40 specs. There are essential no other emissions or waste streams. Additional information is attached.

Products: I have attached some documentation concerning the products.

References :

- Memorandum to John Hughes from Umesh Hattuikudur July 23, 2003
- CWT Promotional Literature www.changingworldtech.com

MEMORANDUM

To: John Hughes
Through: Jim Short
Through: Nancy Marker
Through: John Blevins
From: Umesh Hattikudur
With: Harry Monck Del-EASI
With: Paul Wilkerson, RPAC
Subject: Trip Report: CWT Pilot Plant, Philadelphia Naval Yards
Reference: Tires, File 09.A
Date: July 23, 2003

On Tuesday, July 22, 2003, 1 accompanied Jack Tarburton (DEDO), Paul Sample (Technical Advisory Office), Paul Wilkerson (RPAC), Jim Minner and Brad (DelDOT), and Harry Monck and Edith S (DelEASI) to the Philadelphia, Naval Yards to review Changing World Technology's (CWT) thermal de-polymerization process. We were met by Brian Appel, CEO and Frank Kramer, Executive VP of CWT.

We started out with Mr. Appel giving us a brief history and review of the process. Mr. Paul Baskis invented the technology in the early 1990s and this has been refined through several process improvements which, Mr. Appel said, have resulted in further patents. In 1998, the Gas Research Institute joined CWT in developing this technology, resulting in a Research Facility including a 7 tons/day (TPD) pilot plant in Philadelphia in 1999. CWT has now collaborated with ConAgra Foods, Inc. to build a 200 TPD plant to process wastes from the nearby ConAgra Butterball turkey processing plant. This plant is scheduled to start up the week of July 28, 2003.

Mr. Appel then described the process in a quick overview. The waste material is first slurried with water by processing through a Toronado mixer (such as used in paper pulping) which can handle most wastes easily-water as a diluent/lubricant makes the size reduction "friendly" and low maintenance. The resultant slurry, containing particles at 1/2 inch or below, is fed through progressive cavity pumps (such as used in many slurry handling applications) to the reactor. The pumps are capable of generating high pressure as needed (about 600 psi) and the slurry is heated by waste heat recovery exchangers to about 3 50 oF followed by trim fuel gas heaters (using fuel gas produced by the process) to about 500 T. When the reaction is deemed complete (determined through monitoring of flow rates, pressures and temperatures), the pressure is released in three steps. The first causes sufficient vaporization of steam to generate 100 psi steam, the second produces 50 psi steam, and the final stage produces utility quality steam. Minerals are sepearted out at this point and the liquid then proceeds to the reformers, or as Mr. Appel termed them, the "delayed cokers". This process, used in petroleum refineries, "re-forms" the higher molecular hydrocarbons, breaking down the long chains at about 850 oF also generating "coke" or carbon black. The solids and liquids are separated in continuous centrifuges and then heated and distilled to remove light gases and the remaining water. The resultant light oil product is of high quality, surpassing API 40 specs. There are essentially no emissions or other waste streams.

A question and answer followed, where Mr. Appel and Mr. Kramer responded to several questions including follow-up to answers supplied earlier by mail to questions from Mr. Tarburton (and group) forwarded earlier. Some of the answers follow. Mr. Wilkerson asked for a cost to process a ton of waste (example: municipal solid waste) from the point of feeding the process as raw waste to the point of producing final products for sale. Mr. Appel estimated this cost to be $30-40/ton and that this cost would not vary much with the type of waste presented. However, this cost was based on MRFD (separated) material, not mixed solid waste. Their current design is based on off-the-shelf equipment with no exotic materials or designs. The ConAgra plant is 200 TPD capacity and they expect their next plant (likely the Goodyear Tire waste tire processing plant) to be a 400 TPD facility. Mr. Appel estimated the cost of the 200 TPD plant at about $20 MM and the cost of the 400 TPD plant at about $28MM. Their Philadelphia pilot plant was started up with a 30 day environmental waiver for startup. Mr. Appel said that oil produced from the ConAgra waste at proposed process conditions was approaching 50API quality, which is currently being tested for spark plug ignition engines. However, Mr. Appel expects that the target market will be chemical and plastic producers, due to the high quality and narrow molecular range of the hydrocarbon components. While the original economics were done at a $10-15/barrel sale price, Mr. Appel expects the higher quality oil that has been demonstrated to claim a $35/barrel value. CWT showed a slurry produced by treating tires at 500 oF with water- this was an easily stirred treacle-like paste that contained undissolved steel pieces. CWT has successfully developed a process to treat Philadelphia waste water sludge and is expecting to build a plant for them in the future.

2 10 TPD of poultry waste is expected to produce 69.8 TPD 40API oil at ConAgra. At an approximate sale price of $3 5/barrel (42 gal/barrel; 0. 13 64T/barrel), I calculated the sales value to be $85 for product from a ton of waste poultry.

In response to a question by Mr. Wilkerson, Mr. Appel said that it would not be practical to design and build a unit that would accept a variety of feeds (since Delaware does not produce sufficient waste to justify a 20OTPD plant for a single source). This would mean that Delaware, if interested, would have to look for innovate utilization, such as campaigning a plant that would run, say sludge for a few months, mixed waste for a few months, and tires for a few months at a time.

Appendix IV

MECHANICAL AND BIOLOGICAL SYSTEMS

Wastaway Technology Evaluation

Prepared by Wally Kremer, Del-EASI

Introduction

The Bouldin Corporation in Warren County, Tennessee has a novel, innovative, patented process that recycles 95% of residential Municipal Solid Waste (MSW). The cost is the same or less than sending the waste to a landfill. The Warren County Executive Kenneth L. Rogers is very pleased with the arrangement. His county has received environmental awards including monetary awards for achieving 95% recycle of residential MSW. The state of Tennessee is very proud of this achievement. WastAway's innovative household garbage recycling process has been awarded the prestigious R&D 100 award for 2005. The editors of R&D magazine selected the process as one of the 100 most technology significant products introduced into the market place in 2005.

WastAway has installed a second facility in Coffee County, Tennessee and has sold the technology to Alton Steel Inc. for a recycling and energy producing site in East St. Louis, Illinois on a former Brownfield site.

So what is this process and product! The residential MSW is collected as now with NO separation. (Yard Waste handled separately). The process described in more detail in the process section, involves shredding and grinding and then processing with steam in a Hydolyser with 130-150psig pressure steam. Metals are separated after the Hydolyser. Process meets all Tennessee environmental requirements.

The product produced is called 'fluff'. The appearance and character is like a fibrous, wood pulp. See Product section for more detail. The EPA classifies fluff as compost. Fluff is used by its self or blended with bark or other soil amendment for land reclamation or growing plants. Nurseries are using it in the Southeast and praise the product. The Army Corps of Engineers has used on several army posts.

The fluff is also used as feed to extruders to make rigid products like fence posts and rails, park benches and even for walls. The Governor of Tennessee has a bench outside his office.

The Bouldin Corporation has been in business 45 years and has an excellent reputation for reliable, strong, effective equipment and manufactures mechanical and automated equipment for the nursery industry. Other equipment some to grind large trees and another to handle shell casing including live rounds for the military.

Investment for a two line initial system is only $4million without land and building. This would process as much as 40,000 tons/yr. Bouldin is willing to run tests on Delaware MSW to aid Delaware. Products can be produces from our waste for testing and acceptance.

Summary & Conclusions

The novel patented process can and has **achieved 95% recycle of residential** MSW in Warren County, Tennessee. (Large items and no-compliance materials removed, yard waste handled separately). The solid waste is picked up with NO presorting by the householder. (Maybe a significant help in Delaware). The Bouldin Company and with its connected companies, WastAway and Composite Products Converts the waste into usable products. Metals are also recovered in the process. The output from the process, is a product called fluff, which is a class III compost as defined by EPA standards and regulations. Material safety data Sheets are available- classified as non-toxic. The fluff can be blended with other materials for sale to Nurseries or other soil conditioner uses. The fluff can also be extruded into rigid products. Process and products meet all Tennessee regulations.

The patented, automated continuous process combines shredders, grinders, conveyors, a processing unit and magnetic and eddy current equipment to remove metals.
www.bouldinlawson.com, www.wastaway.com and www.compositeproducts.com provide more information. Facilities were visited in Warren County Tennessee by members of DelEASI. WastAway made a presentation to DelEASI in Wilmington and another to DNREC and DSWA.

Pros
- No separation needed by householder. Pick up residential trash as now. Yard waste separate preferred.
- Investment low - $4million for a two-line system that processes up to 40,000 tons/yr.
- Initial investment to start program low or that needed for smaller jurisdiction.
- Cost equal to or less than tipping fee. Products gain revenue.
- 95% recycle possible- since householder does the same as now. Proven in Tennessee.
- Product is useful in nurseries and other soil applications.
- Potential rigid product line.

Cons
- Market needs development in this area. Bouldin already know to nurseries.
- Delaware waste must be tested to assure no unforeseen issues. Test can be run at WastAway facility.
- Will take a period of time to grow the usage in Delaware.

Recommendation

- Test Delaware waste in the process.
- If successful install a two- line unit in Delaware.
- Pursue private and public financing.

Process- WastAway 95% Recycle of Municipal Solid Waste

The WastAway process converts the Municipal Solid Waste (MSW) that is picked up without separation by the household and converts the waste into useful products. In Warren County, Tennessee the company has demonstrated a 95% recycle rate. The process is a unique patent- protected non-incineration, environmental management system that recycles all household garbage to produce a sterilized, stable product called "fluff".

The process is delivered to the facility-handled by front-end loader, shredded, ground and processed with steam, at 130-150 psig pressure, into fluff. Metals are separated after the processing. Appendix contains more information on the process and the patents. Some of the patents are that cover the process and the apparatus are 5,772,134, 5,558,281, 6,017,475. Patent information in Appendix.

Bouldin & Lawson the original company that later formed the WastAway Company has been in business for over 45 years manufacturing mechanical and automated equipment for the nursery industry. They also produce equipment for the military that crimp spent shell casing, at times containing live rounds. They produce grinders to process large trees. Their experience has been used in innovating the WastAway process to make it rugged, reliable and automatic. On an engineering judgement basis, this process is has sound concepts and is well executed.

The economics of the process are competitive with tipping fees for landfills. Depending on specific location, the process appear to be competitive with $40-$50 per ton tipping fees, as reported by newspapers and the company. One reason is the revenue obtained from the separated metals aluminum and steel and the fluff. Fluff is usable as enrichment for soil, compost and feed for producing solid pieces. More about the fluff in the product section of this report. One ton of garbage yields $10-12 for the aluminum, and fluff yield 3 yards per ton and sells for about $13/ yard. One ton of garbage yields about 1200 lbs. of fluff on dry basis or about 1600 lbs. on a 35% moisture basis the normal moisture content.

The total investment in the process will vary by location. A system of two lines is the normal arrangement, since it provides maintenance time for each line to provide continuos operation. A single line operates at 3 tons/hr and the investment is slightly less than $2million dollars. A two- line system would have an investment cost of about $4million without building and land. For high spot estimate purposes, an additional $1million is allocated for land, buildings and contingencies. (Normal estimating practice). Buildings do exist at Pigeon Point that may well be suitable. Capacity for 360 days /year at 20 hours /day operation which is normal industrial rating system is 43,200 tons/year. Usually operation is more like 322 days/year or 38,640 ~~tons/year. (Limited by garbage collection days). Conservatively the approximate 300,000 tons/year residential~~ MSW in Delaware would require an investment of $40-50 million dollars for 8-10 systems. A financial commitment level that is within reason for Delaware. Initial test system could be only $4-5 million dollars possibly obtained through a Federal grant. The process is compatible to scale-up, so potentially the number of larger lines would be less and the investment may be lower.

Environmentally the process meets all the Tennessee requirements. Major liquid discharge is water from the process steam and the water content in the garbage. In the air leaving the process there are some 1.7 lbs. of VOC's per ton of garbage. This is not a problem in Tennessee. In Delaware with our closeness to limits of non-attainment zone, additional steps may be necessary. The VOC"S can be removed using conventional technologies of adsorbing, scrubbing or used by recycling as fuel to process boiler. Even at 1.7 lbs./ ton this quantity of VOC"S is a small percentage of the methane and other organic compounds released to atmosphere from a landfill with even 75-80% gas collection capability. (Based on literature model of landfill gas releases).

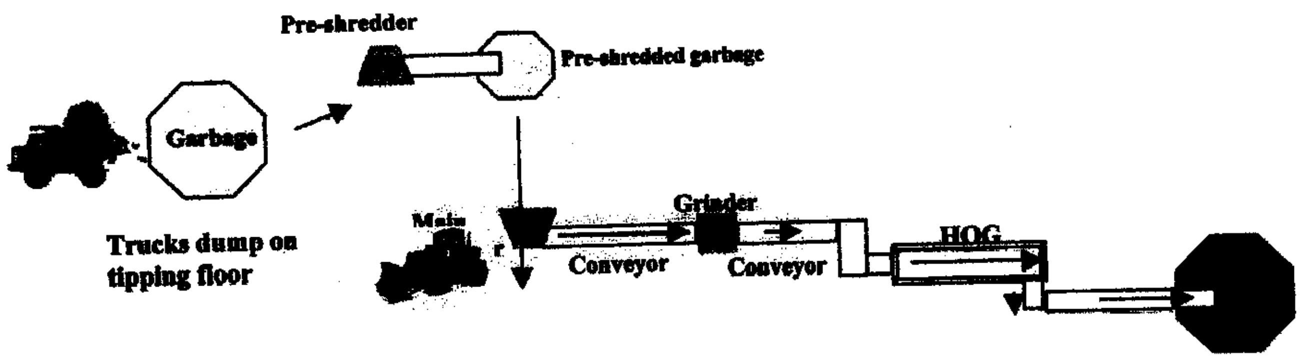
DelEASI members visited the Bouldin- WastAway plant location in McMinnville, TN and toured the process during its operation.

Process Flow Diagram - Unsorted MSW from trucks that collect residential waste dump on the tipping floor inside the building. Any large items like furniture are removed. The MSW goes through a series of grinders and shredders; magnetic rollers remove the ferrous metals. During the patented process the household MSW is submitted to steam at about 150lbs pressure (About 350F temperature) that reduces pathogens to undetectable levels. (Called a HOG- Hydrolysis of Ordinary Garbage) Thirty minutes later, the household waste is transformed into a stable product called "fluff". The aluminum is removed by a non-ferrous separator. The process is an entirely automated rugged mechanical equipment and conveyor system. See attached.

WASTAWAY SERVICES™
A Bouldin Corporation Company

General

The WastAway process is a unique *PATENT-PROTECTED* waste handling system that converts raw, unseparated garbage into a usable product called '***fluff***'. The system is a continuous flow process from beginning to end. Below is a simple block diagram of how the system works:



Garbage is delivered by truck – handled with a front-end loader, shredded, ground and processed into '*fluff*'. From beginning to end (garbage to *fluff*) the process takes approximately thirty(30) minutes

The most unique feature of this system is that it converts the entire waste stream into useful products without curbside separation. This system processes garbage at costs that are competitive with current landfill disposal costs and much less than most recycling program costs. The products are environmentally safe and the need for new landfill space is reduced. Useful products such as landscape timbers, fencing materials, parking stops, compost, mulch and other such items can be produced using "*fluff*" as the core component.

Products – WastAway Process and Composite Products

The initial product from the WastAway process is called "fluff". The appearance and character is like a fibrous, brown wood pulp. The EPA classifies "fluff" as compost. Appendix contains more details on the product. "Fluff" is used by itself or blended with other materials as pine bark and used as a soil amendment for land reclamation or growing medium for plants.

The Army Corps of Engineers with a $750,000 federal grant did extensive tests using fluff as a land reclamation agent and had excellent results. Used initially at Fort Campbell, Kentucky and then Fort Benning, Ga. After an exhaustive analysis for 200 possible organic and heavy metal contaminants and initial germination test with native grasses the "fluff" was found suitable for field tests. The Evaluations indicated that the material is well suited for returning organic materials to soils on degraded training lands. It was also found that large amounts of the material could safely be land applied, further enhancing its usefulness.

Nurseries are using the material using in blends for potting soil. DelEASI members toured the Hale and Hines Nursery Company in McMinnville; TN. and they reported extensive use and their satisfaction with the material Contact is Terry Hines 569 Hale Lane, McMinnville, TN 37110, Phone 931-934-2285. Web Site www.haleandhines.com. Auburn University Department of Horticulture has tested fluff for growing of plants and published the satisfactory results in the Southern Nursery Association 2004 Research Proceeding. Properties of the "fluff" and contaminants are shown in more detail in the Bibliography and Reference section. Analysis by Western Kentucky University shows "fluff" to be 55.90% Carbon, 6.80% Hydrogen, 1.05% Nitrogen, 0.75 Sulfur and 34.86% Oxygen. Heating value was 10,082 BTU per pound. "Fluff" is reported by Corps of Engineers to contain about 1.25% nitrogen, 0.2%phosphorus and 0.25% potassium as nutrients and was measured at 7.2 pH, which is near neutral. "Fluff" contains sodium so a sodium increase was seen in the soil, but no increase was seen in the plants. Appendix has the executive summary of Corps of Engineers report and a power point presentation on the study. This study, other data and behavior of material produced from Delaware material are critical to use of this technology.

"Fluff" can also be used as feed material to an extrusion process to produce solid materials. Another associated company called Composite products produces solid materials. The solid materials can be fence posts, boards and larger beams. One of the items, for example, they produce is park benches. The Governor of the State of Tennessee has one outside his office in honor of the 95% recycle attained in Warren County.

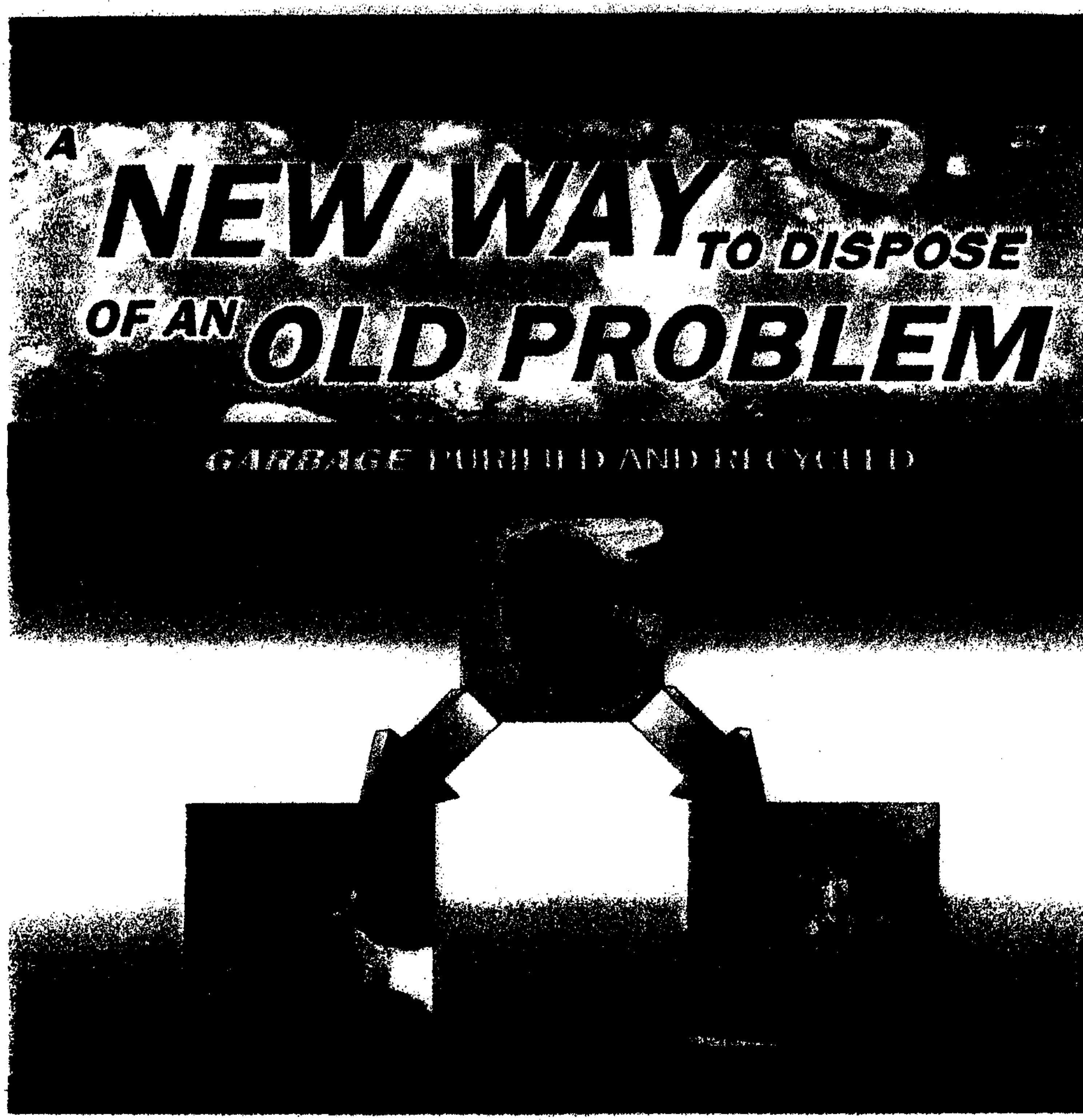
A summary of properties of Composite product evaluations is included in Appendix section on products. A brief summary of properties include; compressive strength about 1,040 psi., modulus of rupture 530-560 psi, dry weight 67 pounds per cubic foot, density about 1.2 times that of wood and ½ that of normal concrete. Performed well after two years of outside exposure and resists acid environments for long period without loss of strength. A summary and index of reports follows.

Marketing

Marketing of the products is a key issue. For "fluff" and mulch mixtures, nurseries have been found to be a major market as potting soil. WastAway reports some 500 nurseries exist within 150 miles around our area. Initial marketing effort is underway. The military posts are another marketing possibility. This is the largest unknown especially in terms of rate of growth of the market and could limit the rate of implementing the technology

The rigid materials made by extrusion must be demonstrated to a larger degree. Retaining walls, park benches, posts, rails etc need longer-term data on life and weathering. Two- year evaluation of posts and rails are available in appendix. Conclusion was the condition of the extruded fence post and rail material after a period of two years showed no noticeable deterioration of surfaces or interior structure, except for curvature in the posts and slight cracking at two corners of the post cross section. One post broke upon removal. Additional studies underway. The potential exists for use as a replacement for treated lumber. In some applications it may be competitive with concrete blocks.

FLUFF RIGID MATERIALS



Bouldin & Lawson

WASTAWAY SERVICES

Composite Products of America

BouldinCorp

Bibliography & References

1. Web sites www.wastaway.com, www.bouldinlawson.com,www. composite products.com
2. *Evaluation of Composted Household garbage as a Horticultural Substrate* - Auburn University study- published in the Southern Nursery association 2004, research proceeding. Report says the WastAway fluff in 40% blends can grow can grow impatiens and petunias as good as three commercial blends now used.
3. *Press Release August 31, 2005,* Awarded by *R&D magazine* one of the 100 awards for technological significant products. Attached.
4. *Press Release April 18, 2005* WastAway sells plant to Alton Steel Inc. Attached.
5. *Public Works Digest* July/August 2004. U.S. Army Installation Management Agency Article – Results of Corps of Engineers research at Fort Campbell on soil and plant recovery with fluff. Article Attached.
6. Test results western Kentucky University on Composition attached.
7. Executive Summary – Solid Waste Recycle and Reuse Processing Technology by Corps of Engineers – Comprehensive summary of Army work. Attached.
8. Composite Products tests of rigid materials by consultant James Walker- attached.
9. Patents- 6,017,475 & 5,772,134 & 5,558,281& patent application 20040041301 Both process and product patents. Abstracts attached.

Appendix IV (cont)

MECHANICAL AND BIOLOGICAL SYSTEMS

Composting

Prepared by Al Ostrand, Del-EASI

History and Science

Composting is a process that represents man's efforts to optimize natures process of decay that we see in a pile of fallen leaves in the forest. Since mankind was first involved in agriculture more than 5000 years ago some form of composting has been practiced by farmers.

Composting produces a soil-like humus which can have various qualities depending on the materials being composted. The science of composting is well known and can be either aerobic or anaerobic. In the united states aerobic composting has been used almost exclusively and is what is described herein.

All organic materials from nature can be composted, from fallen leaves, grass clippings, wood chips, brush, to dead chickens and manure. To optimize the time the process takes moisture and temperature control, as well as carbon to nitrogen ratio [C/N] are critical. In a backyard compost pile it might take a year or more to produce a satisfactory humus. In the most advanced commercial and municipal operations this time is reduced to eight to ten weeks.

In a large scale operation say 100,000 tons per year. Materials are brought to the site by truck, processed through chippers or grinders as needed to reduce particle size, mixed for homogenity and to achieve the proper c/n ratio, and then placed in windrows, up to 8 feet high, 12 to 16 feet wide, and 200/300 feet long.. moisture is optimized at 50 percent and temperature controled between 40 to 60c. To aerate and further mix the windrows they are turned with pay-loaders or specialized machines periodically until the process is completed by natures workers [bacteria, fungi, mites, snails,, earthworms etc.]. the process is brought to 40c plus for five days and to 55c plus for four hours within this period to kill off pathogens in accord with EPA regulations. Since most of natures workers cannot exist above 60 to 65 c close control is required. In the most advanced systems temperature is controlled by forced aeration monitored by temperature and moisture sensors linked to a control computer.

The microbiological organizims in the windrow require oxygen and produce carbon dioxide, oxygen must be kept above 5 percent to avoid anaerobic decomposition and resulting odors. See attachments for details from Cornell University Waste Management Institute

State of the Art System

The W.L. Gore Company's German subsidiary produces and markets the "Gore Cover System" for composting that can be used for facilities processing 10,000 to 200.000 tons per year. A 160,000 TPY plant has been operating in Everett, WA for about one year. This patented covered system minimizes odor, aides. Optimum temperature and moisture control and speeds up decomposition with forced draft aeration. See attachments for further detail.

Anaerobic Composting

Anaerobic composting which mimics the digestive system of animals and produces methane gas which can be used for energy recovery has been tried in europe. This is done in closed tanks under computer control, much like a chemical plant operation. Anaerobic bacteria replace aerobic bacteria and temperature is controlled for optimum gas production. Capital cost appears high and waste water must be treated. This technology is still in early development and has not been tried on any large scale in the united states.

Pros and Cons of Composting

Pro

- Produces a usable humus for which there is a ready market
- Reduces methane emissions to the atmosphere
- The less sophisticated systems can be started on a low capital and operating cost budget
- Some composters are operating as profitable businesses selling their product to nurseries, golf courses, landscapers etc..

Con

- Quality control to meet customers needs in a large scale operation may be difficult.
- Requires space say 25 to 150 acres for a 100,000 TPY operation depending on the system.
- Potential odor problems if the system is not properly control led constantly
- Management is a constant inventory and logistics problem to assure the optimum 30 to 1 C/N ratio.

Further study

More information is needed on costs. Private operations are very careful not to reveal any details that might hurt their competitive position. We can probably get quotations from gore if we get site specific. We should explore costs at municipal or county operations.

Attachments

- Cornell Composting [cc] p1,2. cc Invertebrates MOF the Compost Pile p1,2,3,4. cc Compost Physics p1,2,3,4. cc Compost Chemistry p1. cc Compost Microorganisms p1,2,3,4. Cc Appendix a, Table a 1 Characteristics of Raw Materials.
- Principles of Composting with the Gore Cover System p1,2,3,4,5.
- EPA compost -- new applications for an age old technology
- Trip report – visit on 11/14/2005 to Gloucester Township Municipal Composting Facility, Gloucester, NJ

Trip Report - Visit to Gloucester Township Municipal Composting Facility, Gloucester, NJ, on 11/15/2005.

The visit was made together with DNREC and U of D representatives. The site is a large tract of cleared land surrounded by a screen of trees and brush all bordered on three sides by big timber creek. To comply with NJ state regulations only 25 acres can be used for composting, while another 10 to 15 acres is used for storage and curing of compost.

Only grass and leaves are handled at this facility. Currently the volume is 70,000 yards per year, with capacity for 116,000 yards. Assuming 1/3 grass clippings and 2/3 leaves this converts to a 48,000 ton capacity, based on their current method of operation. During the fall months some 150 truck loads of leaves are delivered per day peaking at 170 truck loads in late November. The facilty handles 14 surrounding towns as well as Gloucester Township. Compost production is 18,000 yards , which when screened yields 16,000 yards of saleable and 2000 of overs which must be landfilled.

The township has a large investment since much of the land was forested and had to be cleared [estimated at over $1m]. this includes a "scat turner" and several 5yard payloaders. This investment does not include cost of land since it was already township owned.

Operating costs are about $250,000 and compost sales some $200,000. There are only some three regular employees, with contract labor being used extensively. A tipping fee of $1.25/yd is charged to the other towns. The facility supervisor has collection responsibilty for leaves, grass and other recyleables within the township. He can refuse delivery to any contaminated loads of leaves or grass. Collection drivers can also refuse curbside pickup of contaminated material.

The operation does not turn a profit and no allowance has been made for return on investment. However the tipping fee has remained the same for some 15 years and should be much higher. It takes 18 months to make compost [windrows are turned 12 to 20 times during this period] so the inventory of material in process is hugh compared to output. Part of this is due to the seasonal nature of raw material delivery, and part to lack of optimum oxygen, moisture, and temperature control, which if optimized could speed up processing time.

Al Ostrand 11/16/2005

Appendix V

PLASMA AND OTHER NEW TECHNOLOGIES

Plasma Gasification or Pyrolysis Report

Prepared by Wally Kremer, Del-EASI

Introduction

Thermal Technologies are and can be used to process Municipal Solid Waste (MSW). Newer technologies produce synthetic gas that is used to generate electricity. The syn-gas is primarily composed of hydrogen, carbon monoxide and methane. One such technology is Plasma.

Several approaches are used. Pyrolysis is a thermal degradation of organic materials in the absence or almost complete absence of oxygen. Gasification is thermal conversion of organic materials in the presence of heat at temperatures normally above 1400 F and in limited supply of oxygen. These two approaches are gaining acceptance in the marketplace versus incineration, which is complete combustion with oxygen.

What is a Plasma? A AC and /or DC electricity passed through an electrode to produce a plasma in a gas at temperatures greater than 7000 C. (12500F). (Some as high as 15,000 – 20,000 C) Plasma companies indicate these higher temperatures used for operations 1500 to 2000 C to decompose the waste to the basic ions and give better temperature control for better environmental performance. Data from various companies on tests indicate excellent environmental performance. Many stages of environmental equipment and control are used to achieve very high efficiencies of collection. Plasma systems are used for medical waste, electrical waste including PCB's and chemical waste destruction.

Plasma systems have been only small capacity for other wastes. In the last 5 years or so larger systems are in operation or are proposed for Municipal Solid Waste (MSW). List of companies and brief information about them is covered separately. Westinghouse technology is in use in Japan with a 300ton/day plant about 100,000 tons/yr. Delaware may require a 1000-1500 tons/day -350,000 to 500,000tons/year plant. Companies and countries plan 500 and 1000 ton/day plants. Companies have test facilities and engineering groups to provide designs and estimates.

Summary and Conclusions

Plasma gasification or pyrolysis is an emerging technology in field of waste management. The use for processing Municipal Solid Waste on a large scale is now being considered. Current most installations are small (10-50 tons/day) and are for medical, electrical and chemical wastes. A larger installation in Japan has been operating at 200 ton/day and is expanded to 300 ton/day (100,000 ton/year). Other units at that size or larger are now planned around the world. No large unit is in operation in the United States only smaller facilities. After successful recycling and composting programs some 350,000-500,000 tons/year

(1000tons/day) of material maybe left in Delaware that may need to be landfilled or processed by a thermal unit.

The plasma gasification system is improved environmentally over the old type total combustion incinerators. The Westinghouse system in Japan is replaced an incinerator and is said to be 100 better in environment discharges. There is potential for better environmental performance with these units and the higher operating temperature that destroys all organic compounds into their elemental components is a key feature. The temperature of the plasma produced by the electrical discharge (sometimes called artificial lightning) is above 7000C (12500F) the temperature of the sun and the decomposition reaction is carried out at 1000- 2000 C, so all the organic compounds break down to their elemental components. A total system has many stages of environmental control equipment to remove impurities. Metals are recovered and a vitrified glass is produced that some say can be sold and EPA approves for landfill. Pilot systems exist for testing and operating system data should be available to determine exact environmental performance. Companies indicate all EPA; European Union and Japanese regulations can be met.

Pros

- The higher operating temperature provides potential for better destruction of organic compounds and possibly enhanced environmental performance.
- Plasma torch has been use in industrial commercial applications for many years and reliability now enhanced and demonstrated.
- Many universities are now studying and many knowledgeable graduates available.
- Academic and other consultants and engineering design companies available.
- Used for destruction of tires, medical, electrical, chemical wastes and now MSW.

Cons

- No large plant built in United States. Only a few larger plants in the world.
- Sophisticated technology
- More energy required to operate than conventional Waste to Energy (WTE) units, although efficiency improving. One company indicates a 4 to 1 gain in energy for fuel output versus energy input.
- High investment – only very-very high spot information available- which indicates Capital cost of $100-300 Million dollars for a 1000-1500 ton/day unit depending on how larger units are scaled up from smaller
- Costs information must be obtained for operating in Delaware. Economics dependent on electrical and costs of alternate disposal means and revenue.
- State of technology could mean higher risk.

Recommendations

- If thermal processes including Waste to Energy concepts are considered, the state of plasma technology emergence should be reviewed.
-If considered a consultant or manufacturing company should be used to provide preliminary design information and a high spot evaluation.

Process Description

The plasma systems will differ somewhat in detail for each company but the concepts are similar. First stage is the plasma generator. A picture of one from the Envroarc web site follows. Electricity is feed to two electrodes of a torch that generates extremely high temperatures. Inert gas is feed through the torch to heat the process gas. It has been said plasma arc torches use electricity to create an artificial lightening bolt with temperatures above 7000 C (12500 F) a temperature hotter than the sun surface.

The MSW is feed into a decomposition reactor. The conditions in the reactor are either those for pyrolysis or gasification with low levels of oxygen. Temperatures are still high in the unit 1000-2000 C (1800-3600 F) which completely destroys the MSW and it is broken down into its basic elemental components. The systems are usually operated at a negative pressure. A conceptual picture of the decomposition reactor from Enviroarc web site follows.

Summary of Companies, Academic Sources

Plasma is a technology used for years in industry. Commercial sized units are now used in waste management. Many Universities have studies on plasma as a frontier in physics. There are many smaller startup companies as well as established companies in the field. This listing is not inclusive of all the companies.

Westinghouse www.westinghouse-plasma.com/gasif.htm
Westinghouse has a testing facility in Madison, PA near Pittsburgh. Dr. Shyam V. Dighe is a recognized expert in the field. Westinghouse has designed plasma reactors for waste treatment and power generation in the 25ton/day (pilot) to 1000 ton/day range. (1000 ton/day adequate for Delaware). They have over 200 patents in the field. Westinghouse was requested by Hitachi, Ltd., Japan to develop WTE (Waste to Energy) as a solution to the dioxin, ash and energy recovery problems of numerous incineration plants in Japan. MSW plasma demonstration plant in Yoshii, Japan had excellent results. Emissions much reduced with dioxins 100 times lower than from the incineration plant. Based on the reliable performance and results the first small commercial sized plant was constructed in Utashinai, Japan at 200 tons/day, uprated to 300 ton/day of MSW. Another MSW plant at Mihama-Mikata. Westinghouse visited Wilmington and made a presentation to the DSWA and others and provided data on plant operation and environmental discharges. References included technical paper presented at Pittsburgh Coal Conference in 2002 and Wilmington presentation information.

Solena www.solena.com
The average sized plant accepts 1000 tons/day of raw MSW. We have about 15 plants in various stages of development around the world including several countries in Europe and Asia. Most of our plants have a capitalization payoff in 5 years. Reference letter from Dennis Miller Chief Scientist and Vice President. Will take visitors to plant in Bordeaux, France. Also have taken visitors to a GM 100ton/day built in 1989 and an ALCAN unit in Canada. Energy produced is 4 times energy required

for operation. The process is thermal plasma gasification with no combustion. Pilot facilities available for testing. The technology converts MSW into low- heating -value synthesis gas. Received U.S. Government Trade Development grant to study the feasibility of a MSW plant in the Czech Republic. The 500ton/day plant investment estimate is $87 million to produce 45MW of electricity.

Enviroarc and Scanarc www.enviroarc.com and www.scanarc.com
Companies in Norway and Sweden respectively. The Scanarc electrode system is well regarded. The web site gives estimated costs and investment for a commercial plant in Europe. Would need to do for Delaware. However, they show about $50 million investment for a 400ton/day plant. Costs and revenue information is provided.

Geoplasma www.geoplasma.com
This company located in Atlanta, Georgia indicates they have collaborated with Georgia Tech University and partnered with Westinghouse. Georgia Tech one of leading plasma research centers.

Peat International, Inc www.peat.com
Peat has facilities in Taiwan and the United States. A 10-15 Ton/day plant in Taiwan processes liquid hazardous waste. They also did a 6-8 ton/day project for wastes in Lorton, Virginia. They indicate Georgia Tech Research Institute is a partner.

Recovered Energy, Inc. www.recoveredenergy.com
Provides detailed information on plasma process technology and environmental controls. They are a consulting and engineering firm. Plasma technology they use is Westinghouse. Web site has technical discussion and a large amount of other information. Technical discussions explain why plasma's high temperature is critical to destruction of all organic compounds. They sate they have investigated 70 different gasification processes, 36 plasma gasification processes, 5 pyrolysis processes and numerous providers of pollution control equipment and gas turbines and by- product producers. They provide education seminars, preliminary project evaluation in 1-2 days.

RCL Plasma and US Plasma www.rcl-plasma and www.usplasma.com
Seem to be connected. Gives information on process.

Startech www.startech.net
Process can collect Hydrogen. Indicate they have signed two contracts for plants in Poland.

Alentec www.alentecinc.com
Discusses plasma and other gasification processes like biomass.

Dutemp www.dutemp.com
English company that claims to be able to build plasma plants to handle up 4000 ton/day of MSW. Web site provides in-depth environmental and economic data. Use both Georgia Tech and a Russian Institute for advisors. Investment for a 4000 ton/day plant is $426 million for

which a net profit of $124 million is claimed. No operating plant is claimed but many potential plants in many counties.

Intergrated Environmental Technologies, LLC www.inentec.com

Now their largest plant 10 ton/day. Larger units are contemplated. Emissions are generally very low. Dioxins are near background in California. Tipping fees and energy prices key to economics. Plasma facilities for destruction of wastes have been built. Some papers published are: Waste Gasification-Test Results from Plasma Destruction of Hazardous, Electronic and Medical Wastes – presented at International Thermal treatment Technologies 2003 conference; Demonstration of Mercury Capture Efficiency During Medical Waste Processing; Destruction of Electrical Equipment and PCB OIL in a Plasma Enriched Melter at IT3 conference in May 2004.

Advanced Technology Research-ATR http://atr.site.org

Discusses a special feed system they combine with plasma system. Their process can be introduced at rate of 100 ton/hour which is 2000 ton/day on a 20 hour day basis. They estimate 8.8 million BTUs per ton of garbage. Will provide costs for the Plasma Arc technology combined with the Air Vortex Pump Continuous feed system for Electrical Power Generation using either standard garbage and /or existing Hydrocarbon fuels. Can locate near and existing power plant and improve air quality management.

Appendix VI

MISCELLANEOUS

Landfill Enhancement Methods

Prepared by Mary Jane Hofmann and Edith Swoboda, Del-EASI

Traditional or Conventional Landfilling Compaction Methods

Most landfills operate by having the collections vehicles unload the waste at the tipping face and then having dozers and steel wheel compactors put it in place. At the end of each day, a soil is placed over the waste. The key piece of equipment in compaction is the steel wheel compactor which breaks up the waste and increases the pressure on the waste.

Factors Affecting Conventional Waste Compaction/Landfill Waste Density

The efficiency of compactors is largely dependent on the use of equipment by the operator. Other key factors are:

- o Proper equipment
- o Properly trained operator
- o Equipment maintenance
- o Refuse Layer Thickness
- o Method of landfilling
- o Number of passes over refuse
- o Slope
- o Other operational controls, e.g. routing of landfill traffic over areas previously filled.

Advantages and Disadvantages - Conventional Landfilling

Some *advantages* to the conventional landfilling and compaction are:

- o It is the least expensive technique
- o Conventional waste disposal techniques are widely accepted and understood
- o If the equipment is used correctly, waste compaction and the resulting capacity is maximized
- o Most flexible in managing difficult types of waste

Some *disadvantages* to conventional landfilling:

- o Compared to other techniques which will be outlined, the waste density maybe somewhat lower resulting in maximum capacity not being realized.

Shredding and Shredfilling

Shredding transforms wastes to a homogenous form that may be more easily and better compacted in the landfill.

Description of Shredfilling

There are two general types of shredders:

- o High speed hammermill shredders;
- o Low speed rotary shredders

Advantages and Disadvantages - Shredfilling

Some *advantages* to shredding waste for landfill are:

- o Daily cover may not be required and after compacting seems to bind better which reduces wind blowing and rodent/bird attacks. The reduction in cover and increase in compaction would result in savings in landfill space.
- o Heavy equipment operation on shredded waste would be easier due to the homogenous shape and size of the waste material.
- o Rodents and Birds would be discouraged from the waste as a food source. (See first advantage.)
- o An estimate on compaction of shredded waste is 32% higher than conventionally managed wastes.

Some *disadvantages* to shredding are:

- o Not all wastes can be shred.
- o Adding another processing step would add capital and maintenance costs to those already required for landfilling.
- o The reduction in daily covering needs to be researched and tested.
- o Maintenance of equipment and resulting downtime is greater compared to conventional landfilling.

Baling and Balefilling

Baling is a process that has been used here in the U.S. and Europe. It involves the high pressure compaction of waste into bales by equipment known as balers, and the subsequent stacking of baled waste in the landfill or disposal area. The area into which bales are placed is known as a balefill. In the U.S., there are a few places (Roanoke, VA., Houston and Dickenson, TX., St. Lucie, Fl.,Northern Cook County, IL. e.g.) using balefilling. In some cases it was done in response to public opposition to the establishment of a new facility.

Description - Balefills

The operation of a baler involves the high pressure compaction of waste by a series of rams in a charge chamber. The compacted waste is then ejected and tied with wire or strapping for transport by truck or rail. They are then stacked like blocks at the operating face of the balefill site. Tarps are often used as the daily cover rather than soil, thus saving landfill space.

Advantages and Disadvantages - Balefills

Some *advantages* of balefilling over conventional landfilling are:

- o Greater compaction of waste.
- o Bird activity at tipping face tends to be lower provided bales do not break apart.
- o Odors tend to be less
- o Soil as a daily cover is reduced by at least 50%. A spray-on mixture can be used (Pozzy Shells).
- o Little or no blown litter.
- o Reduction in differential settlement due to reduced air space in waste mound.
- o Reduced operational cost.
- o Public perception is of a "neater", more aesthetically pleasing operation.
- o Transfer face has the option to operate as a conventional transfer station or baling facility.

Some *disadvantages* of balefilling are:

- o As in shredfills, the addition of another step would raise capital, operating and maintenance costs to those already incurred by conventional landfilling.
- o Historically, there has been high downtime for maintenance and repair.
- o Not all waste can be baled.
- o Potential to prolong leachate production. collection and treatment duration and therefore the monitoring period after closure.
- o Processing capacity of baling plant provides limited flexibility as to varying waste quantities and types.

References

1. & 2. Regional Municipality of Niagara, Long Term Disposal Planning Study , Task D Technical Brief, Identification and Assessment of Alternative Landfill Technologies, by Earth Tech Canada Inc. & Macviro Consultants, Inc.., 2003. This is a review of the current alternative technology made by consultants for the Niagara Region of Canada. Subsequently the municipality joined with the city of Hamilton and a study entitled "Niagara-Hamilton WastePlan" is being made by MacViro Consultants and Jacques Whitford Ltd. This new study considers more comprehensive waste disposal means such as waste conversion to energy.

3. RI DEM/RIRRC Comprehensive Solid Waste Management Planning Study. This is an ongoing study by Rhode Island of the problems of waste management. Size and costs of some balefills sites are given as well as the benefits of balefills. Internet Address:
www.dem.ri.gov/programs/ombuds/outreach/integsw/pdf/balefill.pdf

4. Bader, Charles D. "A New Millenium for MSW Processing.", MSW Management, Elements 2001. Modern balers are making it possible to create "balefills" and they can be "built" above grade on a flat ground.

5. Trade Associations

o National Solid Wastes Management Association (NSWMA) - part of the environmental industry associations which represents companies providing products and services for a better environment. Their "Waste Expo" will be held April 4-7, 2006 in Las Vegas, NV.

o Solid Waste Association of North America (SWANA) - advancing the practice of environmentally and economically sound municipal solid waste management. Their "Waste Con 2006" will be held September 19-21, 2006, in Charlotte, NC.

Appendix VI (Cont.)

MISCELLANEOUS

Source Reduction and Recycling -Alternate Thinking on Waste Disposal

Prepared by Marlene Rayner, Del-EASI

Alternative Thinking on Waste Disposal

"Waste is currently looked on as a stream flowing from society (commerce, households, institutions etc) to landfill – a liability that needs to be "disposed of"(New Zealand Waste Report). This means that municipal waste is the end user responsibility. The technically large scale solutions to this waste disposal issue, along with their technical and purely business economic pros and cons, are well described in other sections of this report.

Because Delaware is small, the state has an opportunity to be a state model of clean, environmentally friendly waste management. To fill in the gap for a fuller analyses of waste handling possibilities, I felt that there were two issues other than purely technological evaluation that needed to be evaluated by citizens and legislators: (1)There is much value in the recycling industry in the US: value in the jobs and small businesses, value of the natural resources themselves, the energy that could be saved by recycling them, and the pollution prevented in the process. All these values have been quantitated and are in Part 1.

(2)The concept of recycling has been furthered refined into a concept called "Zero Waste" (Part 2). Zero Waste questions the concept of "Integrated Waste Management" that is currently associated with landfilling and incineration. Some countries and many communities have opted for this approach, because the best ways to reduce waste are before it gets to the end of the road. (Getting there! The Road to Zero Waste (New Zealand) (<http://www.zerowaste.co.nz/assets/Reports/roadtozerowaste150dpi.pdf>)

"Zero waste" in the recently adopted plan (November 15, 2005) for Palo Alto means diverting at least 90 percent of materials used or which could have been used from being put in landfill. The council also agreed to an interim goal - diverting 73 percent of waste by 2011. The city already keeps 57 percent from the dumps now, better than the state's average of 48 percent. The city generated 166,548 tons of waste in 2003, according to the California Integrated Waste Management Board.
~~(http://www.cityofpaloalto.org/zerowaste/graphics/Strategic_Plan_FInal_100405)~~

Part 1. THE MANY VALUES OF RECYCLING

The percentage of materials in discards in an EPA report shown below illustrates how little of our waste is not recyclable by some means (http://www.epa.gov/epaoswer/non-hw/muncpl/facts-text.htm#chart1).

Paper: 35.2%
Yard Trimmings: 12.1%
Food Scraps: 11.7%
Plastics: 11.3%
Metals: 8.0%
Rubber, Leather, and Textiles: 7.4%
Glass: 5.3%
Wood: 5.8%
Other: 3.4%

NOT RECYCLING MEANS LOST RESOURCES AND ENERGY AND MORE POLLUTION

(http://www.nrc-recycle.org/advocacy/RISEfactsheet6-14 05.pdf#search='Recycling%20Investment%20Saves%20Energy')

The amount of energy lost from throwing away aluminum and steel cans, plastic PET and glass containers, newsprint and corrugated packaging was equivalent to the annual output of 15 medium sized coal power plants. Increasing the recycling rate of these commodities by 10% would save enough energy annually to heat 74,350 million American homes, provide the required electricity for 2.5 million Americans, and save about $771 million in avoid costs for barrels of crude oil.

Recycling conserves energy and landfill space and reduces pollution.

● **Aluminum** -Recycling of aluminum cans saves 95% of the energy required to make the same amount of aluminum from its virgin source. One ton of recycled aluminum saves 14,000 kilowatt hours (Kwh) of energy, 40 barrels of oil, 238 million Btu's of energy, and 10 cubic yards of landfill space. Fifty-five billion aluminum cans were wasted by not being recycled in 2004, which represents approximately $1 billion of aluminum lost to industry. The aluminum can recycling rate in 2004 was 51.2%, down from 68% in 1992.

● **Newsprint** -One ton of recycled newsprint saves 601 Kwh of energy, 1.7 barrels of oil (71 gallons), 10.2 million Btu's of energy, 60 pounds of air pollutants from being released, 7,000 gallons of water, and 4.6 cubic yards of landfill space.

● **Office Paper** - One ton of recycled office paper saves 4,100 Kwh of energy, 9 barrels of oil, 54 million Btu's of energy, 60 pounds of air pollutants from being released, 7,000 gallons of water, and 3.3 cubic yards of landfill space.

● **Plastic** - One ton of recycled plastic saves 5,774 Kwh of energy, 16.3 barrels of oil, 98 million Btu's of energy, and 30 cubic yards of landfill space.

● **Steel** - One ton of recycled steel saves 642 Kwh of energy, 1.8 barrels of oil, 10.9 million Btu's of energy, and 4 cubic yards of landfill space.

● **Glass** - One ton of recycled glass saves 42 Kwh of energy, 0.12 barrels of oil (5 gallons), 714,000 Btu's of energy, 7.5 pounds of air pollutants from being released, and 2 cubic yards of landfill space. Over 30% of the raw material used in glass production now comes from recycled glass.

<u>Savings from the perspective of natural resources and energy conserved</u>
(from the book "Garbage Land" by Elizabeth Royte; Little Brown and Co. 2005)

●**Paper** - Collectively the US consumes more than 80 million tons of paper per year. Paper is 35-40% of waste in North America. Besides saving trees (e.g. NYC's Staten Island Plant claims saving 13,500 trees per day.), recycling paper saves the oil used in the energy intensive logging operations and inside the recycling plant, 25% less energy is consumed than in a virgin wood-pulp operation.

●**Steel** - Recycling scrap steel uses one-third less energy. Every ton of steel recycled saves 1,400 lbs of coal, 2500 lbs of virgin ore, and 120 lbs of limestone - the amount of materials needed to mine and refine new steel.

●**Aluminum** - Recycling aluminum cuts energy use by 94 percent and avoids the same amount of air pollution. To make one million aluminum cans from bauxite ore requires 32 million barrels of crude oil and 5 million tons of bauxite ore.

●**Precious Metals** - Recycling precious metals, such as cadmium and nickel, saves 46% and 75% respectively of primary energy, compared to mining and extraction and refining the virgin ore.

●**Zinc** - Using zinc recovered from alkaline batteries uses 22.5% less energy than extracting it from primary sources.

●**Glass** - Making new glass from old glass saves 50% of the energy, yet less than one-third of the bottles sold in the US are recycled into anything, let alone refilled.

●**Plastic** - In 2003 alone, Americans consumed 13 billion liters of bottled water, much of it in half-liter PET plastic bottles. Plastic bottles are made from oil and natural gas. Had all those 26 billion water bottles been recycled, an *estimated 6.3 million barrels of crude oil equivalent* could have been savedfrom this one product alone (and over 1 million tons of greenhouse gas emissions could have been avoided). This energy saved calculation is for one product. It does not include the 40 million plastic Pepsi bottles Americans trash each day.

RECYCLING HAS REAL ECONOMIC VALUE

Recycling and Reuse Add Value to the U.S. Economy (www.nrc-recycle.org/resources/rei/docs)

According to the study, the recycling and reuse industry consists of approximately 56,000 establishments that employ over 1.1 million people, generate an annual payroll of nearly $37 billion, and gross over $236 billion in annual revenues. This represents a significant force in the U.S. economy and makes a vital contribution to job creation and economic development.

Estimates of Direct Economic Activity

Annual Payroll and Estimated Receipts are in $1,000. Throughput is in Thousands of Tons.

Data Type	Recycling Collection	Recycling Processing	Recycling Manufacturing
Establishments	9,247	12,051	8,047
Employment	32,010	160,865	759,746
Annual Payroll	956,875	3,826,360	29,181,749
Estimated Receipts	1,974,516	41,753,902	178,390,423
Estimated Throughput[1]	191,082	191,082	157,545

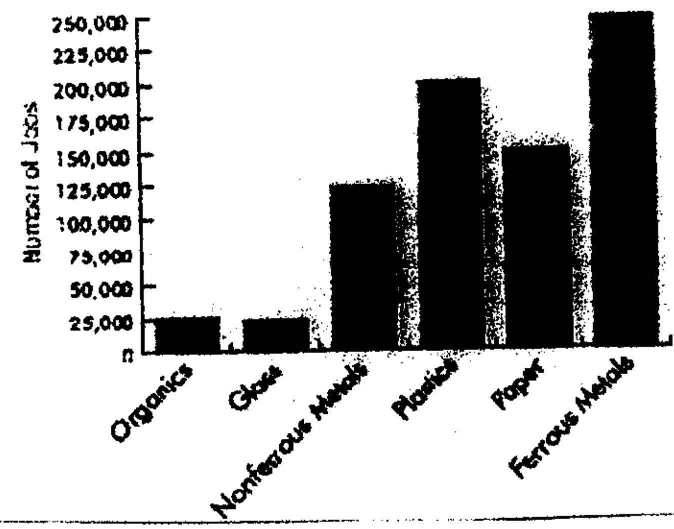
[1] Throughput is amount of recovered material recycled and includes manufacturing scrap sent for recycling. It excludes materials prepared for fuel use and in-house process scrap returned to the manufacturing process. Throughput estimates are summed to avoid triple counting at collection, processing, and manufacturing stages.

Recycling is a Diverse Industry

Recycling is an integrated system that starts with curbside collection of materials by municipalities, involves processing of recycled materials, and leads to manufacturing of new products with recycled content. The study identified 26 different types of recycling organizations. The recycling sector includes long-established sectors like paper and steel making, as well as new entrepreneurial ventures such as composting and plastic and rubber product manufacturers. Four major manufacturing industries account for over half of the economic activity of the recycling and reuse industry:

- o Recycled paper and paperboard mills, which employ 139,375 people and gross nearly $49 billion in estimated annual receipts;
- o Steel mills, which employ 118,544 people and gross $46 billion in estimated annual receipts;
- o Recycled plastics converters, which employ 178,700 people and gross nearly $28 billion in estimated annual receipts; and
- o Iron and steel foundries, which employ 126,313 people and gross over $16 billion in annual estimated receipts.
- o The recycling industry also includes companies that are quickly finding a market niche, including computer demanufacturing, organics composters, and plastic lumber manufacturers.

Recycling Manufacturing Industry Employment by Major Material Group

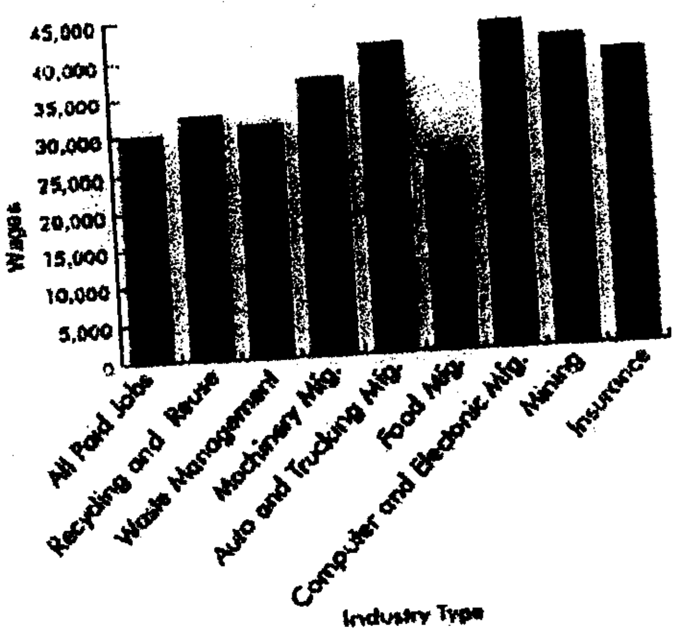


Commodity Type

ecycling is Competitive with Other Major Industries

s a driver of economic activity, the recycling industry compares favorably to other key industries, such as itomobile manufacturing and mining. Especially significant is the finding that recycling far outpaces the aste management industry because recycling adds value to materials, contributing to a growing labor force. ecycling also provides a large number of jobs that generally pay above the average national wage.

Comparison of Industry Employment



Comparison of Annual Wages per Job

Local Recycling and Reuse Spur "Downstream" Economic Impacts

Investment in local recycling collection and processing, as well as strong government policies, spurs significant private sector investment in recycling manufacturing and promotes economic growth. The study tallied this "indirect" impact of recycling on support industries, such as accounting firms and office supply companies, for a total of 1.4 million jobs supported by the recycling and reuse industry. These jobs have a payroll of $52 billion and produce $173 billion in receipts.

Spending by employees of the recycling and reuse industry also contributes indirectly and adds another 1.5 million jobs with a payroll of $41 billion and produces receipts of $146 billion. The recycling and reuse industry also generated roughly $12.9 billion in federal, state, and local tax revenues, with 80 percent going to federal and state government.

Contribution of Recycling and Reuse to Government Revenues - Direct Effects Revenues (in $ millions) http://www.ergweb.com/projects/jtr/content/10-12-01/econ/rei-rw/charttext.htm - c3

Industry Sector	Federal	State	Local	Total
Recycling Collection	200	100	100	400
Recycling Processing	700	400	300	1,400
Recycling Manufacturing	5,400	2,600	2,100	10,000
Reuse/ Remanufacturing	600	300	200	1,200
Total	6,900	3,400	2,600	12,900

Contribution of Recycling and Reuse to Government Revenues - Total Effects Revenues (in $ millions)

Industry Sector	Federal	State	Local	Total
Recycling Collection	300	200	100	600
Recycling Processing	1,700	800	600	3,200
Recycling Manufacturing	20,500	9,900	7,800	38,200
Reuse/ Remanufacturing	2,100	1,000	800	3,900
Total	24,600	11,900	9,400	45,800

Reuse Businesses Contribute Significantly

The reuse industry is widespread and ranges from more traditional establishments such as local thrift stores and antique shops to more recent, dynamic operations such as computer demanufacturers, pallet rebuilders, and materials exchanges. As a whole, the reuse industry employs nearly 170,000 workers in more than 26,000 establishments nationwide. The reuse industry also supports an annual payroll of $2.7 billion and generates revenues of approximately $14.1 billion.

Analysis of Economic Activity for the Reuse Industry

Establishments	26,716
Employment	169,183
Annual Payroll	$2,747,498,000
Estimated Revenue	$14,182,531,000

CURBSIDE RECYCLING SHOWN MORE EFFECTIVE

Table 9. Curbside Collection Recycling Performance by City Size and Drop-off Recycling Performance in 1989 and 1996 (Constant 1992 Dollars)

Population Class	1989 Tons Recycled	1989 Cost per Ton	N	1996 Tons Recycled	1996 Cost per Ton	N	Percent Change
Under 5,000	881.35	$57.24	13	1,368.12	$142.37	17	+148.72
5000 - 10,000	681.28	104.17	14	1,087.36	120.41	14	+ 15.59
10,001 - 25,000	1,483.13	113.26	19	2,393.84	113.38	18	+ 0.11
25,001 - 50,000	2,980.62	111.20	12	9,115.36	70.35	10	- 36.74
50,001 - 100,000	1,803.53	136.87	12	11,147.01	89.98	11	- 34.26
Over 100,000	4,114.53	166.07	14	29,562.43	102.63	12	- 38.20
Means for all Curbside Programs	1,884.43	$114.95	84	8,294.99	$110.63	82	- 3.76
Means for just Drop-off Cities	560.46	$104.60	18	1,363.83	$195.10	18	+ 86.52

Reference: Recycling Policy and Performance:Trends in Participation, Diversion, and Costs
By David H. Folz, Associate Professor and MPA Coordinator, Department of Political Science
University of Tennessee, 1001 McClung Tower, Knoxville, TN 37996-0410

http://web.utk.edu/~dfolz/recycle1.html

A variety of studies suggest simply giving each residence or business a large can (or colored trash bags, the first is free, but the next bags cost for disposal) for single stream recycling of mixed dry materials is one of the most effective means of enhancing participation in curbside recycling programs –whether it is 'mandatory' or 'voluntary' participation. However, there is a strong participation ethic as long as the process is simple. In 2004 the estimated statewide diversion rate in California was 48% (http://www.ciwmb.ca.gov/LGCentral/Rates/default.htm). Each year the California Integrated Waste Management Board's (CIWMB) Diversion, Planning and Local Assistance Division (DPLA) reports on statewide progress toward the diversion goals of the Integrated Waste Management Act of 1989.

Average Costs of Curbside Recycling

(http://www.ciwmb.ca.gov/LGLibrary/Innovations/Curbside/Costs.htm)

The SWANA study of more than 110 California communities found an average curbside recycling cost of about $2.40 per household per month. This information is somewhat weighted toward larger communities. Combined curbside recycling and yard waste program costs showed patterns of lower costs in communities with the following characteristics:

Older recycling programs.

More suburban or rural areas.

Lower population areas.

Areas that used mixed waste MRFs.

ZERO WASTE CONCEPTS

Description

Zero waste is a philosophy and a design principle for waste movement that goes beyond recycling to take a far reaching "systems approach" to the flow of resources and waste through society. Throughout the process of developing a zero waste policy and implementation plan, staff will work with a task force of community and stakeholders, including local businesses, to ensure that the proposed elements of the zero waste policy are viable options. Zero Waste requires funding for infrastructure to assist residents, industry, business and institutions. This assistance program audits waste, helps broker waste diversion to businesses or recyclers

Beyond Recycling! Zero Waste ...Or Darn Near

by Eric Lombardi, Executive Director of EcoCycle, Inc., September 2001

(EcoCycle is based in Boulder, Colorado. Eric is a leading national spokesperson for Zero Waste.)

Specifically, Zero Waste has five basic tenets:

o **Redesigning products and packaging.** Planning in advance to limit product resource consumption, toxicity, and waste, and recovering materials through reuse, recycling, or composting - designing products for the environment, not for the dump.

o **Producer Responsibility**. Manufacturers are held responsible for the waste and environmental impact their product and packaging creates, rather than passing that responsibility on to the consumer. The end result is that manufacturers redesign products to reduce materials consumption and facilitate reuse, recovery and recycling.

o **Investing in Infrastructure, Not Landfills or Incinerators**. Rather than using the tax base to build new landfills and incinerators, communities can continue to invest in new facilities designed to take the place of a landfill or incinerator. Combined with social policies and market signals, the technological advances of the 1990s can easily support the diversion of 90% of society's discards.

o **Ending Taxpayer Subsidies for Wasteful and Polluting Industries**. Pollution, energy consumption and environmental destruction start at the point of virgin resource extraction and processing. Manufacturers use virgin resources for raw material partly because tax subsidies and other social policies make this a cheaper and easier alternative than using recycled or recovered materials. Additional public subsidies exist to keep "disposal" costs through landfills and incinerators artificially low by not assigning significant economic penalties to the harmful emissions produced by these facilities.

o **Creating Jobs and New Businesses from Discards**. Wasting materials in a landfill or incinerator also wastes business opportunities that could be created if those resources were preserved. According to the Institute for Local Self Reliance's report Wasting and Recycling in the United States 2000, "On a per-ton basis, sorting and processing recyclables alone sustains ten times more jobs than landfilling or incineration." The report points out that some recycling-based paper mills and recycled plastic product manufacturers employ 60 times more workers on a per-ton basis than do landfills. The report adds, "Each recycling step a community takes locally means more jobs, more business expenditures on supplies and services, and more money circulating in the local economy through spending and tax payments."

Institute for Local Self-Reliance (ILSR) is one provider of technical assistance
(http://www.ilsr.org/recycling/zerowaste/index.html)
Twenty-five years ago, many solid waste planners thought no more than 15% to 20% of the municipal waste stream could be recycled. Today numerous communities have surpassed 50% recycling, and many individual establishments — public and private sector — such as office buildings, schools, hospitals, restaurants, and supermarkets have approached 90% and higher levels. See Recycling Record-Setters. A handful of innovative communities in the U.S. and abroad have endorsed zero waste goals and planning. Del Norte, California, was the first U.S. community to adopt a zero waste management plan. Seattle's current solid waste plan has adopted zero waste as a guiding principle. In 2002, the San Francisco Board of Supervisors adopted a 75% landfill diversion goal by the year 2010 and a long-term goal of zero waste. (San Francisco is already at 62% landfill diversion.) Other California communities are moving in this direction as well; Palo Alto, Berkeley, Oakland, San Diego. The zero waste movement is now international and growing exponentially, due in no small part to these "early adopters."

ILSR provides technical assistance to communities interested in reducing the flow of materials to landfills and incinerators and embracing zero waste as a vision and planning tool for the future. Since 1989 the Institute has targeted specific cities and worked on an extended basis to make waste management an integral element in an economic development strategy. In these communities our efforts include:

1. designing bidding procedures that encourage local ownership of material processing facilities;
2. creating or expanding community-based recycling operations;
3. developing scrap-based manufacturing joint ventures between business and community development corporations;
4. establishing industrial parks for the exclusive or preferred use of scrap-based manufacturers; and
5. helping communities divert 50 percent and more of their municipal waste stream.

Since 1990 our efforts have helped to establish more than 15 businesses with about 250 employees and attract about $20 million in new investment to low-income and working class communities.

This Zero Waste Planning Web page features innovative and model practices and policies that can be replicated in other communities. GrassRoots Recycling Network Zero Waste Web Site (www.grrn.org)

This Web site includes many resources and links on zero waste.

http://www.zerowasteamerica.org/MunicipalWasteManagementReport1998.htm

ZWA's 1998 U.S. "Municipal" Waste Management Report

Waste Disposed (or Generated - Recycled) + Imports + Exports ÷ Population = Performance

ZERO WASTE AMERICA's ... TOP TEN!

Rank	Best Mgmt tons/person/yr	Worst Mgmt tons/person/yr	GenerateMost (tons/yr)	RecycleMost (% of generation)	ImportsMost (tons/yr)	ExportsMost (tons/yr)
1.	S. Dakota 0.400	Nevada 2.132	California 45,000,000	Washington 48%	Pennsylvania 6,300,000	New York 4,000,000
2.	Wisconsin 0.580	Kansas 1.879	New York 28,800,000	New Jersey 45%	Indiana 2,674,000	New Jersey 2,300,000
3.	N. Dakota 0.628	S. Caroline 1.588	Florida 23,617,000	Minn/S.Dakota 42%	Michigan 1,838,000	Missouri 1,756,000
4.	Colorado 0.649	Delaware 1.491	Texas 21,738,000	Maine 41%	Illinois 1,300,000	Maryland 1,200,000
5.	Oklahoma 0.663	Utah 1.484	Georgia 14,645,000	Florida/Tenn 40%	Oregon 1,067,000	Washington 989,000
6.	Minnesota 0.679	New Hampshire 1.471	Michigan 13,500,000	New York 39%	Kansas 1,000,000	Ohio 600,000
7.	Idaho 0.732	Indiana 1.432	Illinois 13,386,000	Arkansas 36%	Mississippi 800,000	Massachusetts 549,000
8.	Missouri 0.761	Hawaii 1.342	Ohio 12,339,000	Virginia 35%	New Hampshire 700,000	Minnesota 412,000
9.	Lousiana 0.769	Georgia 1.333	N. Carolina 9,843,000	S. Carolina 34%	Ohio 668,000	California 408,000
10.	Maine 0.784	Missouri 1.316	Tennessee 9,496,000	GA/MO/MA 33%	Wisconsin 656,000	North Carolina 330,000